ORGANIZATION OF NARRATIVE DISCOURSE IN CHILDREN AND ADOLESCENTS WITH ACUTE TRAUMATIC BRAIN INJURY

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Children with a recent history of TBI often demonstrate impaired memory, which can be affected by impaired attention, processing speed or impaired verbal information processing. The purpose of this study was to determine if qualitative differences exist among the narrative recall of TBI patients that is not adequately accounted for by standard scoring methods. Sixty-six TBI subjects ranging in age from 6 to 16 were given the Wide Range and Memory and Learning (WRAML) Story Memory subtest and selected subtests from the Wechsler Intelligence Scale for Children – Third Edition (WISC-III). Mean elapsed time since injury was 53 days. Recall of the story on the WRAML subtest was hand-recorded by the examiner. A supplemental scoring method accounted for differences in length, errors, and disorganization. Comparisons were made to a randomly selected control group consisting of 16 hospitalized subjects between 7 and 15 years with no history of head injury, neurological condition or event. Findings suggest the WRAML Story Memory subtest is relatively robust in providing information regarding the quality of recall, with the exception of not accounting for the addition of erroneous details. Subjects with both cortical and subcortical injuries were more likely to add superfluous details to their stories. Results also demonstrated significant differences between the TBI subjects and control group in how well the stories were recalled,

primarily in the order of details recalled and in retention after a 30 minute delay. Location was not a significant predictor of narrative organization.

Although using this comprehensive supplemental scoring system a regular basis has practical limitations, hand-recording the narrative takes relatively little time and does appear to provide useful additional information concerning the nature of the child's verbal memory difficulties. Furthermore, the more knowledgeable the child, parents and teacher are about these difficulties and about remediation strategies, the more likely the child will have a successful learning experience upon return to the classroom.

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CHAPTER 1

INTRODUCTION

Every year, 200 out of every 100,000 children in the United States will suffer from a traumatic brain injury (TBI). TBI is the most common injury among children and the leading cause of childhood death and disability in this country (Roman, Delis, Willerman, Magulac & Demadura et al., 1998). Some of the consequences of TBI, such as memory and attention problems, are obvious and are the focus of rehabilitation services. More subtle neurological sequelae such as verbal memory deficits, may not show up until later (Levin, High, Ewing-Cobbs, Fletcher, Eisenberg, Miner & Goldstein, 1988). For example, children ages 7 to 12 with early mild to moderate TBI can have reading difficulties up to two years post injury (Shaffer, Bijur, Chadwick & Rutter, 1980, Wrightson, McGinn & Gronwall, 1995). This may be due to the development of verbal memory skills over a long period of time (Levin, 1988).

It is not uncommon for children with severe TBI to have difficulty remembering, organizing and retelling a story that has been told to them. Since narrative discourse (story re-telling) is a complex interaction of memory processes, attention, information processing and communication skills, problems in any one of these areas may impact the rest (Chapman, 1995). Thus, an examination of the child's ability to recall a story can illuminate more subtle problems that should be addressed in planning rehabilitation strategies (Chapman, Culhane, Levin, Harward, Mendelsohn, 1992, Ewing-Cobbs, Bruce, et al., 1992). A child who has difficulty remembering a story told to them will consequently have problems in "real life" settings such as the classroom where they are expected to remember volumes of information told to them at one time. However, few studies have examined what subtle differences exist in the quality of narrative recall or story re-telling, among TBI children and adolescents. Possible injury-related factors may include severity, type, location, and the age of the child at the time of injury.

Mechanisms of Brain Injury

The devastating effects of brain injury following an accident can be etiologically complex. The mechanisms of brain injury are in the mechanical stretching and shearing of nerve fibers resulting from rapid acceleration or deceleration of the head. This results in wide-spread diffuse intracranial bleeding and ischemia. In addition to localized cerebral damage, focal intracranial lesions such as hematomas and contusions are commonly found (Mattson & Levin, 1990, Levin, Mattis, Ruff, Eisenberg, Marshall, et al., 1987). Hypoxia which often occurs, causes irreversible cell death due to oxygen deprivation. (Comment by David McCullough, Washington, DC in Levin, High, Ewing-Cobbs, Fletcher, Eisenberg et al., 1988).

The cortices of the brain most vulnerable to closed head injury are the orbitofrontal and anterior temporal areas. These focal areas of damage are particularly susceptible to contusions, hematomas, and intracerebral hemorrhages

(Levin, Fletcher, Kusnerik, Kufera & Lilly, 1996). Diffuse subcortical brain injury involving subcortical white matter often appears as a consequence of TBI, regardless of injury severity. This white matter damage may interrupt connections between the frontal lobes, other cortical regions, and subcortical regions, including the limbic system (Ommaya & Gennarelli, 1974). Additional secondary injuries, which can be either intracranial or systemic, can further jeopardize the health and recovery of a brain-injured child. Secondary intracranial injuries can be the result of ischemia, edema, enlargement of contusional hemorrhages, or impairment of constant cerebral blood flow due to disregulation. Systemic injury include hypercarbia, hypoxia, hypotension, anemia, electrolyte imbalance, hyperthermia or other metabolic disturbances including intravascular coagulopathy and release of catecholamines.

Injuries are commonly classified as either focal or diffuse (Stone, Ghaly, DiGianfilippo & Crowell, 1994). Focal injuries are localized to a limited area of the brain and are the result of a mechanical injury which occurred at the time of primary or secondary impact. Types of focal injuries are intracranial hematomas, contusions, lacerations and general brain swelling, and may not appear until hours or days following the initial event. Diffuse injuries are the result of widespread shearing or rotational forces accompanied by loss of consciousness, concussion or prolonged traumatic coma due to seconday ischemic or anoxic effects. Vehicular injuries commonly produce diffuse injuries while blunt assault or falls commonly produce focal injuries. Other methods of injury classification may include acceleration vs. deceleration, cortical vs. subcortical, and contact vs. non-contact.

Thus, the physiological changes following a TBI is often complicated. Any combination of focal, diffuse or secondary injury can occur, which complicates brain injury presentation. Injury severity is not always readily apparent on computerized tomography (CT) or magnetic resonance imaging (MRI) scans, and it is not uncommon to have a child sustain a shearing or diffuse injury and present in a coma and have a negative or normal initial scan (Hymel, 2001).

Neuropsychological Sequelae to Brain Injury

Just as there can be complicated injury presentation, subsequent neuropsychological effects may also be subtle and/or profound. Memory and attentional impairments often seen in children and adolescents with a sustained TBI. A study by Filley, Cranberg, Alexander & Hart (1986), that administered, among other tests, a WISC-III to 53 children and adolescents found diffuse memory impairment among TBI children. Children six years and under had better social and academic outcome than children 7 to 18 years old. A separate three year follow-up study of head injured children found lingering deficits in the areas of cognition, academic success and functional abilities among TBI children, which was attributed in part to impaired storage and retrieval memory processes (Fay, Jaffe, Polissar, Liao & Rivara, 1993). Seventy-two children between the ages of 6 and 15 at the time of injury were matched with controls on the basis of age, gender, grade and premorbid behavior. At one year follow-up, the moderate and severely injured children were worse than controls on 40 out of 53 variables. (Age was not examined as a variable). Impairment of verbal learning and visual spatial skills were seen in 44% of children and adolescents with TBI twenty-two to twenty-eight days after injury, following the resolution of posttraumatic amnesia (Levin & Eisenberg, 1979b). When comparing the three age groups, 0-5 years, 6-12 years and 13-18 years, there was more pervasive cognitive impairment in the 6-12 age group.

In a study examining differences in verbal and performance recovery patterns as measured by the WISC-III, post-TBI children tended to have a stable verbal IQ, while their performance IQ plummeted over the first year. Over the course of several years, performance IQ tended to gradually recover (Max, Lindgren, Knutson, Pearson & Ihrig, 1997, Filley et al., 1986). The stability of verbal IQ over time may imply that it may not be a sensitive measure in identifying children with TBI who are having critical, but subtle difficulties in verbal information processing. Reading acquisition skills can be delayed (Shaffer, Bijur, Chadwick & Rutter, 1980, Wrightson, McGinn & Gronwall, 1995). Learning difficulties and impaired story-telling are often seen as well (Chapman, 1995, Levin & Eisenberg, 1979b). Story-telling involves many cognitive tasks, including comprehension, attention, memory and verbal fluency. Verbal fluency tends to decrease with left and right frontal lobe abnormalities or diffuse deep white-matter and gray-matter lesions more so than dorsolateral surface abnormalities of the frontal lobe (Levin, Culhane & Fletcher, 1994).

Problems in adaptive functioning can also be a TBI sequelae. In a study by Bijur, Haslum & Golding (1989), teachers reported observing more hyperactivity in children with a history of a mild head injury when compared with the rest of the class. Post-traumatic stress symptoms and problems in adaptive functioning can be a problem for up to one year in children and adolescents that have had severe TBI (Filley, et al., 1986, Levi, Drotar, Yeates & Taylor, 1999).

These studies demonstrate that some children have significant difficulty returning to their premorbid level of cognitive functioning following a traumatic brain injury, and it is possible that their frustration with these problems may contribute to problems in adaptive functioning, as well. There may be subtle differences in cognitive sequelae among children that affects their ability to learn new information after returning to school that are not easily identified by standardized measures. Possible predictors of difficulty appear to include location and severity of the injury, and the child's age at the time of injury.

CHAPTER 2

LITERATURE REVIEW

Severity as a Determinant of Cognitive Recovery

Research suggests that severity of diffuse brain injury is a primary determinant of cognitive recovery in both children and adolescents (Levin, Eisenberg, Wigg & Kobayashi, 1982, Levin & Eisenberg, 1979, Levin, Grossman & Kelloy, 1976). Severely injured children ranging in age from 6 to 18 perform less well on IQ tests than both mild and moderately injured groups (Levin & Eisenberg, 1979).

A global IQ deficit can be found in severe TBI children who were injured before the age of thirteen which is significantly related to impaired memory storage (Levin & Eisenberg, 1979b). In Levin & Eisenberg's study, both the children and adolescents demonstrated substantial recovery one year later. Yet, two and one half years later, the younger group's performance on measurements of IQ were virtually the same as they were at one year, with no significant improvement. Mild and moderate TBI children were not significantly impaired within the first year, and the sharp pattern of recovery did not exist among the mild and moderate TBI children, as was seen in the severe group.

Severity of injury has frequently been measured using the Glasgow Coma Score (GCS) (Ewing-Cobbs, Fletcher, Levin, Hastings, & Francis, 1996; McDonald et al., 1994). According to the Brain Trauma Research Center at the University of Pittsburgh Medical Center, severe is classified as a GCS score of less than 9 in the emergency department or upon hospital admission. Moderate is classified as a GCS score of 9 to 12 or higher together with an operative intracranial lesion or abnormal CT findings. Mild is classified as a GCS score greater than 12, no abnormalities on CT, no operative lesion and a length of stay less than 48 hours (Marion, D., 1999). These are scores based on verbal and motor responsiveness, and are determined by an assessment given by an medical staff in the examination room upon admission to the hospital, and recorded in the hospital chart. Although slight variations in its usage are found among studies, such as combining pre and post GCS scores after admission to the hospital (Ewing-Cobbs, et al., 1996) most studies take the lowest GCS score within the first 24 to 48 hours (Teasdale & Jennett, 1974, Martin, Donders & Thompson, 2000). Other indicators, such as length of unconsciousness, have been used, as well. Levin, Eisenberg, Wigg & Kobayashi (1982) found length of coma had a strong positive relationship to cognitive outcome, as measured by performance on a verbal word list. Dikmen, S., Machamer, J.E., Winn, H.R. & Temkin, N.R. (1995) found a curvilinear relationship between duration of coma and neuropsychological effect sizes. Post-traumatic amnesia (PTA) is also a good measure of injury severity. Standardized methods such as the Children's Orientation and Amnesia Test (COAT; Ewing-Cobbs, Levin, Fletcher, Miner & Eisenberg, 1990) have demonstrated significant prognostic value. Scores on the COAT have been found to predict cognitive problems, particularly in the areas of attention and memory during the first 12 months following injury (Massagli, Jaffe, Fay, Polissar, Liao & Rivara, 1996, Ewing-Cobbs, Levin, Fletcher, Miner & Eisenberg, in press), although these predictors of outcome (duration of coma, impaired consciousness and post-traumatic amnesia) may be related more to injury recovery, rather than injury severity (McDonald et al., 1994). Magnetic resonance imaging of focal lesion volume has also shown promise as a sophisticated measure of injury severity and cognitive outcomes (Fletcher et al., 1996), but is often unavailable. GCS scores are commonly recorded on all patients who are admitted into the hospital following head trauma. In a comparison of ten different measures of severity as predictors of neurobehavioral and functional outcome, McDonald et al. (1994) found that two of the indices that best predicted both early and one-year outcomes were 1) days to a Glasgow Coma Scale score of 15; and 2) initial total Glasgow Coma Scale score. Its severity has a direct relationship to neurobehavioral outcome (Levin, Gary & Eisenberg, 1990), learning and memory (Levin, Grossman, Rose & Teasdale, 1979), general performance (Winogron, Knights & Bawden, 1984), and the Halstead Impairment Index (Gensemer, Smith, & Walker, 1989).

In adolescents, verbal memory problems are directly correlated with severity of injury (Levin, High, Ewing-Cobbs, Fletcher, Eisenberg, Miner & Goldstein, et al., 1988). In children, the correlation is less consistent. However, since verbal memory skills develop over a longer developmental interval, extended follow-up may demonstrate the late appearance of verbal memory deficits in children who had apparent sparing of function (Levin et al., 1988).

Age as a Determinant of Cognitive Recovery

A widely held view is that a younger child will recover more fully from TBI by virtue of the younger brain's "neural plasticity." There is indeed some evidence that younger children are less susceptible to head injury sequelae. This is best documented in a shorter duration of post-traumatic coma in children when compared with adults and a better prognosis in younger patients (Pazzaglia et al., 1975, Frank, Frank & Gaist, 1975). On the other hand, there are reasons for predicting that early head injury may have a more marked effect on later learning. Hebb (1942) suggested that brain injury was most likely to affect new skills and leave intact those already acquired. If this is the case, one would expect to find evidence to support the fact that younger children are generally more affected by the inury. Many studies have certainly not found a sparing of younger children (Levin, Eisenberg, et al., 1982). Children of all ages with TBI appear to be vulnerable to post-traumatic cognitive deficits, however, the type of deficits may vary with age. In a review of research literature on severe head injury, Ewing-Cobbs, Fletcher, & Levin (1985) stated, based on both research review and experience, that preschoolers ages 3 to 5 have more of a tendency to toward generalized cognitive impairment (attention, motor, intellectual, language and visuospatial disturbances), while school-age children and adolescents (ages 6 to18) have predominantly memory, visuomotor and attentional difficulties. Adolescents (ages 13 to 18) may also exhibit problems with later-developing functions such as planning, social judgment and use of strategies. This age effect was seen in a study by Levin & Eisenberg (1979a) that examined children with head injuries of different severity, including 14 children 6-12 years of age and 24 adolescents 13-18 years of age. The neuropsychological assessment measured language, visuospatial function, memory, somatosensory function and motor speed. For the children age 6-12 years there were deficits in all areas, with their scores falling two or more standard deviations below the mean for normal children the same age. They suggested the fact that a child's brain is more "holistic" in nature than adults may explain why diffuse brain injury is sometimes tolerated less well among younger children when compared with adolescents or adults. Dennis, Wilkinson, Koski, & Humphries, et al. (1995), found lower Wechsler Verbal IQ scores in children who were injured prior to age 7 than children who were injured at an older age. Ewing-Cobbs, Fletcher, Levin, Francis, Davidson, et al. (1997) report low Verbal IQ scores on the McCarthy Scales of Children's Abilities in young children with mild to moderate TBI when compared with older children.

How does one explain the poorer prognosis in younger children when, in experimental (animal) models, brain injuries produced early in life are associated with the greatest degree of functional recovery? This may be due in part to the differences between simulated lesions produced in a laboratory and real pediatric clinical injuries. Damage to the human brain during infancy and childhood disturbs cerebral maturation and growth. This interferes with the acquisition of higher, complex functions, which depend upon the successful completion of primary maturational stages. Many areas are responsible for acquiring new information and interpreting incoming stimuli. If they are damaged early in development, it can disrupt the normal processing of information and thereby limit the acquisition of new information which in turn affects the development of high-level functions. Recovery time is also much longer in humans when compared to animals, and it may take months or even years to recover from a traumatic brain injury (Marion, 1999).

Although there is accumulated evidence that both age and level of severity is related to neuropsychological sequelae in children with TBI, there is still a considerable amount of missing information. For example, the relationship between particular verbal deficits and the functional recovery, rehabilitative and/or academic outcome is still relatively unknown. Older children may be able to do better after returning to school because they have predeveloped compensatory skills such as verbal self-coaching and/or mediation that they were learned skills before injury. For example, children younger than 13 years of age with mild injuries have demonstrated poorer visual recognition memory than their adolescent counterparts, who appear to utilize strategies such as verbal mediation to facilitate recall (Levin, High et al., 1988, Levin, Eisenberg, et al., 1982).

Location as a Determinant of Cognitive Recovery

Developmental-neuropsychological models typically refer to the three neuroanatomic axes of the brain: the left-hemisphere/right-hemisphere axis; the anterior/posterior axis; and the cortical/subcortical axis (Rourke, 1982, Bernstein & Waber, 1990). This allows us to apply what we know about relationships between lesion locations and function in the adult brain, as a framework for understanding about childhood neuropsychological functioning (Goldman-Rakic, 1987, Yeates, 1995). The cortical areas most vulnerable to TBI are the anterior temporal lobe and the orbitofrontal lobe.

Temporal lobe. Verbal information processing requires that the information be stored into the memory processes, and both adults and children with temporal lobe damage often demonstrate significant memory loss. Scoville & Milner's (1957) studies on adult amnestic patients suggest there are distinctions between short-term and long-term memory , and clarify the specific role of the mesial temporal lobe and diencephalic structures in the consolidation of new memories (Squire, 1987). Two structures in the diencephalon- the dorsal medial nucleus of the thalamus and the mammillary bodies of the hypothalamus, are associated with Wernicke-Korsakoff syndrome, which is the inability to make new memories. The dorsal medial nucleus appears to be the primary region for this, and focal damage to this area in monkeys is sufficient to cause memory impairment (Aggelton & Mishkin, 1983, Zola-Morgan & Squire, 1985).

Levin & Eisenberg (1979) found that children with closed head injury that involved the mesial temporal lobe demonstrated impaired storage and retrieval processes. Major areas in the mesial temporal lobe structures that are related to memory impairment include the anterior temporal cortex, the hippocampus and the entorhinal cortex. The entorhinal cortex relays afferents and efferents to and from the hippocampus, which lies just posterior to the amygdala and projects to the mammillary bodies via the fornix. The mesial temporal lobe structures take information that has been organized by the prefrontal cortex and allows it to be consolidated and stored in long-term memory (Baddeley & Hitch, 1994). Using the Logical Memory subtests of the Wechsler Memory Scale, Miller, Lai and Munoz (1998) found that patients 14 years and older with localized lesions in a formerly intact hippocampal area had a significant drop in verbal and visual recall, regardless of the condition of the surrounding excised entorhinal cortex. This suggests that the hippocampus is more important than the entorhinal cortex for the recall of newly learned information. Postoperative performance was also lower among those who lost an intact hippocampus when compared to those with preoperative hippocampal pathology, suggesting that reorganization of memory had taken place in the latter group.

Frontal Lobe. The prefrontal, orbitofrontal cortex and the basal forebrain areas also contribute to memory function. Children and adults who have sustained injury to these areas can demonstrate memory impairment. The basal forebrain area lies in front of the optic chiasm, and includes the nucleus accumbens, septal nuclei, the nucleus of Meynert and anterior hypothalamus. The prefrontal cortex appears to be closely related to effective verbal memory abilities. It is more developed in humans than in any other species, but develops last in relationship to other areas of the brain. The frontal lobes mediate the highest forms of mental activity, such as creativity, abstract reasoning, and conceptual abilities (Milner & Petrides, 1984). Even though it is still an immature system, children as young as eight to ten years of age will exhibit increased EEG frequency in the dorsolateral frontal region during verbal working memory tasks, such as word categorization and digit memory (Fermandez, Harmony, Silva, Galan & Diaz-Comas, 1988). Additionally, MRI studies have found that abnormal signal intensity occurs most often in the frontal lobes among post-TBI children (Benyhill, Lilly, Levin, Hilman, Mendelsohn & Brunder, 1995, Mendelsohn, Levin, Bruce, Lilly, Harward, et al., 1992).

Levin, Culhand, Fletcher, Mendelsohn & Lilly (1993) found a relationship between frontal lobe lesion size and verbal memory performance among children and between the dorsolateral and orbitofrontal regions and verbal working memory (Levin, Culhand, et al., 1993).

One of the functions of the frontal lobe region is to organize and categorize new information, and the ability to spontaneously organize new information is related developmentally to the age of the child (Neimark, Slotnick & U1rich, 1970). Younger children tend to use less of an organizing system than older children, adolescents, or adults. Functional changes in children's behavior which occur between the ages of 1 ½ and 5 years, and again between the ages of 5 and 10 years, indicate a fundamental reorganization of their attentional and executive processes. These functional changes correlate with physiological changes in the frontal lobe of children (Stuss, 1992, Thatcher, 1992). The use of deliberate and spontaneous mnemonic strategies (i.e. organizing into categories) that are necessary for efficient storage of verbal information does not appear until late childhood and develops throughout adolescence (Levin, High, et. al., 1988).

More specifically, younger children may often have the ability to organize, but may not be aware that organization would be beneficial. In a study in which children were asked to re-arrange animal pictures, older children frequently organized the pictures into categories. Kindergarteners and first graders who were encouraged to "organize" the pictures adopted an organizational strategy and later demonstrated better recall. In comparison, same-aged children who were not encouraged to "organize" the pictures showed poorer recall (Moely, Olson, Halwes, and Flavell, 1969). Third and fifth graders were more likely to spontaneously use an efficient organizational strategy. Younger children differ from adolescents and adults in how many concept categories they implicitly know, which will pose natural limitations to the way in which new information can be stored. In addition, they tend to group information together if it is presented simultaneously, rather than by meaning, context, or similarity (Matlin, p. 475). Deficits in verbal memory or organization skills affects quality of recall, and these are not uncommon in children with traumatic brain injury. In a study that compared narrative discourse in children with TBI who had acute language impairment, the most pronounced deficiencies were in the level of cognitive organization of the text (Ewing-Cobbs, et at., 1998). Specifically, Chapman et at. (1992) identified more disorganized discourse profiles in children with frontal lobe injuries. This suggests that frontal lesions may disrupt the organizational scheme that guides formulation of discourse, as proposed by McDonald (1992) who theorized that discourse performance among groups is related to frontal lobe functioning because the high correlation between performance on tests sensitive to frontal lobe function and quality of discourse.

Levin, High, et al., (1988) examined the semantic organizational skills in children and adolescents of various ages in order to determine if maturation moderated the effects of injury on memory abilities among TBI patients. They were interested in seeing if verbal memory was spared in younger children much like the sparing of delayed response in young rhesus monkeys with dorsolateral frontal lobe lesions. In Goldman' s studies, adult monkeys that had similar dorsolateral frontal lobe lesions demonstrated impairment

(Goldman, 1974, Goldman & Alexander, 1977). When the young monkeys were two years of age, they began demonstrating an impaired delayed response for the first time, which corresponded to the time of frontal lobe maturity. Using a verbal word list to assess verbal memory, Levin, High, et al. (1988) found that memory deficits were present in all age groups (6 to 8, 9 to 12, 13 to 15) up to one year following mild, moderate and severe injury. Memory abilities were recovered to age-appropriate level in these patients within one year after mild or moderate head injury. Since there was no interaction with age or severity of injury using this verbal measure, it is possible that the test was not sensitive enough to measure subtle verbal memory problems among the younger children. It would have been beneficial if the severely injured group had been retested in adolescence in order to measure the effects of frontotemporal region injury, when organizational and mnemonic skills subserved by this area normally appear.

Memory Processes

Working Memory

Encoding. Attentional abilities are also commonly affected by TBI which in turn can affect adequate encoding of new information to be remembered. Attention is a multidimensional construct that involves several processes, including arousal, alertness, vigilance, capacity and selection processes (Greenham, 1998). Unfortunately, there is not a consistent methodology for measuring attentional abilities among TBI children and adolescents. Furthermore, because there are multiple models of attention and different levels of analysis, it is difficult to draw overall conclusions based on outcome studies.

Attentional processes both affect, and are affected by the child's cognitive, behavioral and neurological state, which further complicates its separate examination (Fletcher, 1998).

Ewing-Cobbs, Prasad, Fletcher, Levin & Miner (1998) examined attentional abilities after pediatric brain injury, using Mirsky's five-factor model composed of focus/execute, encode, shift, sustain and stability constructs (Mirsky, Anthony, Dun, Aheam & Kellam, 1991). Focus/execute refers to the ability to concentrate attentional resources on a task, identify salient elements and perform motor responses in the presence of distractors. Digit Symbol/Coding (Wechsler, 1974), Stroop Test (Stroop, 1935), and Trail Making Test Parts A and B (Reitan & Davidson, 1974) are tests that have been used to measure this construct. Encode refers to retaining information while carrying out cognitive operations. It involves sequential registration, recall and mental manipulation of numerical information. The WISC-III Digit Span and Arithmetic subtests are often used to measure this construct. Shift refers to the ability to shift attention or focus from one stimulus to another as the situation demands. Wisconsin Card Sorting Test (Heaton, Chelune, Talley, Kay & Curtiss, 1993) and Trail Making Part B (Reitan & Davidson, 1974) are tests used to measure this attentional construct. Sustain refers to the ability to give focused attention to a task over an extended period of time while responding rapidly to target stimuli and inhibiting response to distractor stimuli. Continuous performance tests such as Conners Continuous Performance Test (CPT) or the Gordon Diagnostic System (Gordon Systems, Inc., 1987) assess this ability. Stability is the variability of response time and the error rate over time, which is commonly measured by the variability of responses on continuous performance tests.

Mirsky also attributed anatomical correlates to the various attentional constructs. The focus/execute construct is superior temporal cortex, inferior parietal cortex, and structures comprising the corpus striatum. The sustain construct is associated with rostral midbrain structures, midline and reticular thalamic nuclei. Stabilization of attention may also be related to midline brainstem and thalamic structures. Shifting attention is dependent upon the prefrontal cortex, including the anterior cingulate gyrus. Encoding depends upon the hippocampus and amygdala.

According to McKay, Halperin, Schwartz, and Sharma (1994), focused attention normally develops by approximately age 7 while sustained attention develops throughout adolescence. Because it takes longer to develop, sustained attention may be less established and more vulnerable to disruption by a traumatic brain injury that occurs early in life (Ewing-Cobbs, et al., 1998).

Severe TBI is associated with widespread cerebral damage such as cellular injury at the area of focal impact and secondary damage resulting from hypoxia, ischemia, and increased intracranial pressure. Ewing-Cobbs and colleagues (1998) have suggested that this widespread cerebral injury coupled with focal damage may affect multiple dimensions of attention. They found effects of age at injury and severity of injury across several attentional domains, with the most common deficits occurring after severe TBI and on tests that required speeded motor responses. Correcting for differences in speed, there was an interaction between age and severity on the coding/digit symbol subtest, where younger children with mild to moderate injuries did less well than older children with mild to moderate injuries. Severely injured children did less well regardless of age.

Younger children also had slower age-corrected scores on both Part A and Part B of the Trail Making Test. The severely injured group also had more commission errors than less severely injured children did on the continuous recognition test, suggesting deficiencies in focused attention. Rourke (1989) also demonstrated that children with TBI had attentional difficulties.

He devised a continuum scale of white matter impairment, with problems of inattention being a component of the continuum. He found that children with TBI had particular difficulty in both focused attention and shifting attention.

Storage. The concept of working memory refers to a short-term memory system that allows for the temporary holding and manipulation of a limited amount of information during the performance of a range of cognitive activities, such as comprehension, learning, and reasoning (Baddeley & Hitch, 1994). According to the model proposed by Baddeley & Hitch, there are interacting systems, one for verbal information processing (a "phonological loop", one for visual-spatial processing ("visuospatial sketchpad), and one that acts as an executive over the other two (the "central executive"). The phonological loop is able to keep a limited amount of acoustical information for approximately two seconds, after which the memory traces begin to fade unless there is a rehearsal. The visuospatial sketchpad is specialized to process and store both visual and spatial material, independent of the phonological loop. The central executive acts to direct attention, hold and organize a limited amount of new information so that it can be worked with immediately or efficiently stored in long-term memory. It also retrieves information from long-term memory so that it can be briefly held and/or manipulated (Baddeley & Hitch, 1994, CMS, p. 14). The prefrontal region is vital to this role, and in fact, a relationship has been found between prefrontal lesions and impaired word fluency (Benton, 1968).

Retrieval. Memory failure has been attributed to either forgetting, or failing to retrieve what is stored away in memory. There are three basic hypotheses that give causal explanations for "forgetting" (Anderson, 1995). The decay hypothesis asserts that memories weaken as a power function of time. An example of this is contained in Ebbinhaus' classic experiment that illustrated rapid forgetting followed by slower forgetting. The interference hypothesis claims that other memories interfere with retrieval of a target memory. This is particularly true if there are multiple associates to the same item. A classic example of this is the difficulty children have in learning multiplication table facts. There are only about one hundred facts, but they are difficult to learn because the same numbers appear in multiple equations (Anderson, p. 250). The retrieval-cue hypothesis states that retrieval of memory requires cues that may no longer be accessible, for example, performance on recognition tasks is better than on recall memory tasks because of the availability of cues. All three hypotheses are generally expected to contribute to some degree to "forgetting".

This process of encoding, storage and retrieval is very difficult for many children with severe TBI. Levin, Eisenberg, et al. (1982) and Levin & Eisenberg (1979) found persistent impairment of storage and retrieval of verbal information in children with severe TBI, as compared with an age-matched group of children with less severe injury. In a study examining children who were within one month resolution of post traumatic amnesia, Jaffe, Fay, Polissar, Martin & Shurtleff, et al., (1992) found that more severely injured children had greater difficulty recalling information when compared with mild or moderate groups. The groups were fairly similar in terms of their recognition skill, suggesting that the level of retention across the groups was the same in spite of the differences in recall. Yeates, Blumenstein, Patterson, & Delis (1995) found similar results in their study of patients with severe TBI. They showed a disproportionate improvement from recall to recognition testing, suggesting a retrieval deficit. There was also an excessive amount of intrusion responses when compared to the mild and moderate group and the control group.

Hierarchical theory of memory

Discourse theories have suggested that while text recall is a verbal memory task, it is better accounted for by a hierarchical theory than by working memory (Kintsch & van Dijk, 1978). According to hierarchical theorists Kintsch & van Dijk (1978), new textual information is stored in a buffer system, which is part of short-term memory. As new information is presented, it is added to short-term memory and it is interpreted with the assistance of the old information that is still contained in the buffer.

Verbal information is stored in the form of propositions. A proposition is the smallest unit of knowledge that can stand as a separate assertion; that is, the smallest unit to which you can apply a true or false judgement (Anderson, p. 221). Propositions allow for semantic meaning to be applied to the information, and this is aided by old propositions that are still contained within the memory buffer system.

With the addition of new information, older information is transferred to long-term memory in propositional, or meaningful form (Kintsch & van Dijk, 1978). This theory may explain why semantic information is more easily remembered than sensory information. A study by J.R. Anderson (1974b) gave support to this fact. In this study, subjects listened to both meaningful and non-meaningful sentences, and showed rapid forgetting of the non-meaningful distinctions while retaining the meaningful distinctions (Anderson, 1974b). In a similar study using sentences, subjects tended to remember the meaning of a text rather than its exact wording. (Anderson, 1974a). Words that are still in the buffer are recalled much more accurately than words that are no longer held in the memory buffer.

Kintsch and van Dijk's theory has been extended to include large pieces of text, or more complex verbal material, which is also stored in propositional records, or "chunks" (Kintsch & van Dijk, .1978, Anderson, p. 224). More complex material requires tapping into "concept categories."

Verbal Information Processing Impacted by TBI

Verbal information processing is a complicated process, and the ability to sufficiently attend to new information is just one of many steps. Additional steps include hearing the speech sounds, storing a representation of the sounds in short-term memory and locating the meanings of the words in semantic memory. The speech sounds must then be organized into constituents, the meaning of the constituents must be determined, and the constituents must be combined to figure out the meaning of the entire sentence. Finally, the exact wording of the constituents must then be forgotten, and only the gist retained in memory. It is a simultaneous process that, in many respects, is a type of problem-solving (Neimark. Slotnick & Ulrich, 1970).

Simply hearing, or perceiving speech sounds involves a complex interaction. Unlike letters in a sentence which are presented one by one, phonemes, or sounds, are transmitted almost simultaneously and are modified by surrounding phonemes. According to speech perception theorists Cole and Jakimik (1980), context and sound pitch help provide cues for interpretation. Thus, we use not only data, but also knowledge and experience to interpret speech sounds and "arrive at a single best guess for the message we think we hear" (Cole & Jakimik, Matlin, p. 259). It involves both "bottom-up" and "top-down" processing.

Communication Abilities Impacted by TBI

The ability to recognize, categorize and express speech sounds also involves multiple sensory modalities, including phonological processing and speech production. Tertiary language processing occurs primarily in the temporal and/or parietal lobes, and damage to these primary sensory areas can impact higher-level language processing skills, such as receptive and expressive language. Recovery from damage to these regions appears to be affected by age at injury. In a study that examined language abilities in infants and preschoolers with TBI, Ewing-Cobbs, et al., (1989) found a relationship between receptive and expressive language deficits at baseline and at 8 months after injury, and found that expressive language was more affected than receptive language. Expressive language was also significantly more impaired in children ages 4-30 months at injury than in children ages 31-64 months at injury (Ewing-Cobbs, Miner, Fletcher, &

Levin, 1989). These results support other studies that have shown that children generally show more rapid and complete recovery from acquired aphasia than adults (St. James-Roberts, 1979). A younger child's brain has a greater potential for intrahemispheric reorganization among the regions subserving language than an older child or adult (Levin & Eisenberg, 1979).

In adults, lateralization effects are evident during different verbal tasks. For example, differences in EEG activity are seen between the left and right hemispheres during lexical tasks among normal adults (Fernandez, Harmony, Silva, Galan & Diaz-Comas, 1998). Although the two hemispheres perform simultaneous lexical processing, their profile of activity is quite different (Anaki, Faust & Kravetz, 1997). The left hemisphere is responsible for literal sentence processing, comprehension, integration and suppression, while the context, meaning and figurative aspects of language is carried out primarily by the right hemisphere in normal adults (Anaki et al., 1997, Chiarello, 1991, Joanette, Goulet & Hannequin, 1990, Zaidel, 1990). Younger brains are not as lateralized in terms of language processing.

The "plasticity" of children's brains is also seen in their ability to adapt to new languages. Children younger than twelve are able to learn first or second languages much more quickly than their older counterparts. In his book, Biological Foundations of Language, E.H. Lenneberg reports that during this "critical period", children who suffer a severe TBI before the age of about 10 are able to recover full language function. Only 60% of children over the age of 12 suffering from a severe TBI are able to recover full language function. In general, children with severe TBI have more significant linguistic impairment than children with mild TBI, however, there is a great deal of variability in linguistic recovery evident within the severe group (Ewing-Cobbs, et al., 1998).

Levin, Eisenberg, et al., (1982) found that language problems, including anomia, comprehension of oral language, and writing persisted at least six months after severe TBI. Winogron and associates reported that verbal fluency deficits were still present one year after severe TBI. Jordan & Murdoch (1994) identified late effects from 10-34 years following severe TBI sustained during childhood. Although overall language scores were in the average range on a standardized test of adolescent language development, scores were lower for the severely injured patients than for controls in the areas of lexical recognition and retrieval, and auditory comprehension of grammatically complex commands.

Story Recall Used as a Measurement of Impairment After TBI

Many studies that examined verbal memory with TBI children have used a word list format. The advantage of the word list format is that it is systematic, and can be used to measure perseverations, intrusions and false positives on recognition. However, a disadvantage of using this approach is that it may not be as directly applicable to a classroom setting, where the child is expected to remember the gist of more narrative discourse. Human information processing is seldom a matter of rote learning (Bartlett,1932). Information is often given in a conversational or narrative context within the school setting, and in order for the child to experience success, they must be able to learn and retain information that is given in this manner (Roman, Delis, Willerman, Magulac & Demadura et al., 1998).

For this reason, narrative discourse, or story recall, is one of the more valuable ways to explore pediatric language, attention and memory abilities because of its potential application to real-life settings (Chapman, 1995). Chapman, Culhane, Levin, Harward & Mendelsohn (1992) compared the narrative discourse of twenty normal children with twenty children who had sustained a TBI within the last five years. Recall was scored in the areas of language structure (i.e., number of words and sentence complexity), information structure (propositional analyses), and flow of information (efficiency of expression). The vocabulary subtest from the WISC-R (Wechsler, 1974) was included to provide a measure of knowledge for both concrete and abstract words. A test of verbal list recall was also used to account for potential working memory deficits. Children with severe TBI were impaired in recall when compared to the control group in both language and information structures. They demonstrated a disrupted story structure primarily in terms of omitting critical setting and action information. This severe group also differed from the mid/moderate TBI group on amount of information recalled. Left hemispheric patients produced narrative that was more simplified at both sentential and discourse levels. The authors postulated that frontal lesions may disrupt the organization schema, which guide discourse formulation because of the narrative profiles of their patients with frontal lesions. However, this study was unable to control for age at injury, which may have been a possible confound.

There are age effects seen by narrative recall that are less obvious on word list tasks. For example, Piaget (1926) stated that when children between 6 and 8 years tell stones, they often fail to respect temporal order, confuse cause and effect relations and produce less complete stories than adults. They may also overuse or confuse pronouns, making it difficult to determine who is doing what to whom. Fraisse (1963) reported that young children jumble the correct sequence of events when retelling stories. Korman (Yendovitskaya, 1971) also reported that children often neglected the original sequence of events, although the errors were "accompanied by logically explainable 'jumps.'"

Word list recall may not demonstrate these effects. Results of a study by Mandler and Johnson (1977) which compared quality of recall among young children and adults found that the capacity for organized, sequential ordering was extremely high for all groups. In word list tasks, they found that children are capable of organized retrieval when list structure was provided.

Because of the structure of stories, children should be able to recall stories in better temporal order than with other types of prose, such as instructions on using a mechanical device (Piaget, 1926, Thorndyke, 1975). If the story is constructed well, it should provide the necessary structure for young children to be able to give an organized, sequential recall of the story (Thorndyke, 1975, Mandler & Johnson, 1977, Ewing-Cobbs et al., 1998).

Verbal Information Deficits and Narrative Discourse

Discourse refers to the use of communicative language in context (Ewing-Cobbs et al., 1998). It reflects the interrelationship of lexical, syntactic, semantic, and pragmatic linguistic functions as well as cognitive functions associated with planning, sequencing, and goal regulation. Discourse studies may illuminate the impact of certain cognitive deficits, such as memory, on communicative abilities that could guide effective rehabilitation strategies (Chapman et al., 1992).

Chomsky (1957, 1965) proposed that people understand sentences by transforming the surface structure of sentences into deep structure, or "kernel" form. This process is reversed during speech production or writing. The theory of Kintsch & van Dijk (1978) divides text into two categories labeled "microstructure" and "macrostructure". According to their model, the microstructure includes individual words, sentences and their relationships in the text. It also includes linguistic structure and cohesion (the connection of semantic relations between parts of the narrative, for example, when one part of the narrative is depending upon the interpretation of another part). Campbell and Dollaghan (1990) found initial differences in microstructure between the spontaneous narratives of brain-injured patients and controls over a 13-month period. Although the final performance at 13-months was similar in both groups, they reported a great deal of variability among individuals in terms of deficits and recovery pattern throughout the 13-month period.

More robust group differences have been found between children with TBI and control groups on a macrostructure level; that is, the relationships between large units of text representing the main ideas conveyed by the text, such as the theme or gist (Kintsch & van Dijk, 1978, Ewing-Cobbs et al., 1998). For example, Chapman et al., (1992, 1995) examined gist recall in stories and found a significant loss of core information following severe TBI, resulting in impoverished narratives. In their 1992 study, Chapman et al. also reported disruption in story grammar characterized by a failure to signal a new episode with setting information and omission of essential action information in a story retelling paradigm. Several studies have found that sentence structure is simpler and sparser among children and adolescents with TBI. Chapman, Levin, Wenek, Weyrauch & Kufera (1998) found that, when compared to controls and mild to moderate children, severe TBI children produce fewer words and sentences. Jordan and Murdoch (1994) identified late effects from 10-34 years following severe TBI sustained during childhood. Although overall language scores were in the average range on a standardized test of adolescent language development, scores were lower for the severely injured patients than for controls in the areas of lexical recognition, retrieval, and the auditory processing of grammatically complex sentences.

Thus, there are several areas of concern when looking at verbal information processing deficits among children with TBI. These include memory, attention, language processing, and organization skill. Story recall tasks involve all of these areas, and the child's ability to recall a story accurately relates closely to the ability to accurately recall information told in narrative form in "real life" settings, such as the classroom. Subtle discourse problems have been found on story recall tasks, and these tasks may be more sensitive than story generation tasks when identifying more subtle deficits (Ewing-Cobbs et al., 1998). Other infrequently studied variables that may be related are relationships between discourse performance, brain injury severity, neuroimaging findings, etiology, and age of injury, as the retention of certain information and the loss of other information is a result of interacting linguistic grammar and cognitive functions (Chapman et al., 1992, Kintsch & van Dijk, 1975, Thorndyke, 1977, Ewing-Cobbs et al., 1998).

It is suggested that TBI children may be at risk for having these deficits. It is important to identify children who may have subtle language or verbal processing deficits, before they slip through the system and experience frustration, academic and/or behavioral problems. Research suggests that they can be more readily identified in their performance on tasks that emphasized the general structural characteristics of the story rather than specific content. This would suggest that focusing on the macrostructure of narrative discourse in this population would be beneficial in identifying subtle problems in this population, rather than focusing on microstructure.

According to Erickson (1995), story recall represents the most naturalistic, potentially fruitful, and least explored way of examining verbal information processing (Erickson, 1995). Scoring discourse can be problematic, however. For example, in story recall, the main structure and logic of the story are encoded, along with some striking phrases, and the recalled version often takes a somewhat different form, using different wording and involving minor elaboration. Attempts to score stories have failed to reflect this reality (Erickson, 1995). Ordinarily, careful attempts to allow for the inevitable modifications are captured in fragments, which are equally scored. The result of this equal treatment of fragments, or "gist" scoring, is that it is dependent upon the adequacy of the word or phrase used to replace a given fragment. Attempts to create a more accurate scoring protocol have only been marginally successful. Several proposals have been made for ordering idea units in terms of their importance to the overall story but none have found their way into clinical usage (Kintsch & van Dijk, 1978), Thorndyke, 1977, Waters & Lomenick, 1983, Zelinski et al., 1984). Erickson (1995) suggests that as a first step, a distinction should be made between the central elements of the story and the peripheral details. Prototypical stories should be created which illustrate in descending order the extent to which recall is well organized. Clearly one conglomerate score cannot accurately characterize how well a child has responded in the areas of organization, attention to detail, omissions, distortion and/or elaboration.

Research has found that TBI children perform significantly lower on Story Memory than children with reading disabilities or attention problems (Duis, Adams, Sheslow, Robins & Luerssen, 1996). This suggests that narrative recall may recognize subtle differences in verbal performance that may otherwise go unnoticed. By recognizing these differences, more effective interventions designed for the individual may be prescribed for these children. Language deficits in relation to cognitive deficits among TBI patients has demonstrated high degrees of individual variability (Hinchliffe, Murdoch, Chenery, Baglioni & Harding-Clark, 1997, Chapman et al., 1995).

Summary and Critique

The neuropsychological sequelae to pediatric brain injury primarily consists of attention and memory, but broad cognitive and adaptive changes can be seen as well. More subtle impairment may not appear until later in the child's life. In terms of attention, TBI children have problems with sustained and focused attention, and in their ability to shift attention sets. In the area of memory, primary problems involve the encoding and retrieval of information. Both attention and memory affect verbal information processing, which is also commonly seen in children and adolescents with TBI. Children who are younger at the time of injury may at times appear to recover as easily from language deficits when compared with adolescents and adults. However, there is some evidence that longer-term, subtle verbal defects may exist that are not obvious until the adolescent years, when higher level cognitive functions, primarily subserved by the dorsolateral and orbitofrontal regions, fully develop. Frontal and temporal areas are highly susceptible to damage during TBI, and these areas are involved in language processing throughout development.

Severity of injury is the primary determinant of recovery among both children and adolescents. However, the relationship between verbal memory deficits, and outcome measures such as academics or rehabilitation, is still unclear. This is primarily due to the variability of design in measurement of verbal memory, patient population, elapsed time since injury, measurement of severity and questionable validity of word lists in predicting academic performance among studies. For example, verbal IQ scores may stay relatively stable, suggesting they may not be an adequate measure of verbal recovery over time. Alternatively, significant differences in story-telling has been found among groups of TBI patients over time when compared with controls. Narrative discourse provides rich and useful information on cognitive complexity, organizational skills, cohesiveness, comprehension, recognition and retrieval. However, a standardized scoring system has not yet been adopted, making comparison studies difficult.

Statement of Problem

Though there have been a variety of instruments used to measure narrative recall, existing literature suggests that narrative discourse may be one of the most overlooked, but effective methods of identifying subtle impairments in verbal information processing.

Furthermore, several skill sets exist within an overall pattern of discourse which could differentiate between TBI sequelae. Current measures may be too general to account for these qualitative differences, risking the loss of potentially useful information. For example, one of the most common measures of story recall is found in the Story Memory subtest on the Wide Range Assessment of Memory and Learning (WRAML). Scoring for the subtest is structured in such a way that one child may recall details of the story in a disorganized fashion and obtain the same score as another child who recalls the gist of the story, retells it in sequential order, but cannot remember details such as character names. Thus, it does not differentiate qualitatively between children who recall the "gist" versus children who recall random details; between children who tell the story in an sequential or organized fashion, and children who do not; and between children who provided impoverished narratives and children who provided a much longer discourse that included erroneous or extraneous information. These differences may contribute to significant difficulties in school when the child attempts to understand and remember new information that is verbally presented.

Purpose and Research Questions

Children who do not recall in an organized fashion may be suffering from subtle deficits resulting from diffuse memory or executive function problems. Differences in individual performances may be reflective of differences in cognitive sequelae, may demonstrate poorer rehabilitative outcomes, and might identify a subgroup of children who would benefit from focused therapy designed to improve memory, planning and executive function. By providing a supplemental scoring scale to a standard story recall task (WRAML), this study explored possible subtle differences in quality of recall in relationship to injury severity, location and age, that might otherwise be overlooked by the standard scoring system. Thus, the purpose of this study was to address the following questions:

1) Is there a significant relationship between the injury location and quality of narrative recall? Three separate classification systems were used to define injury location. One type of classification divided injuries by the exclusive involvement of either frontal, left hemisphere, right hemisphere, bilateral without frontal involvement and bilateral with frontal involvement, as indicated on follow-up MRI or CT scans. The second method of classification defined injuries as cortical, subcortical or both, and the third method was to classify injuries as either focal, multifocal or diffuse. Quality of narrative recall was defined as length of discourse, errors, and order of narrative recall, and was measured using the supplemental scoring system.

2) Is there a significant relationship between age at injury and quality of narrative recall? Age of injury was on a continuous scale and was obtained from hospital records. Quality of narrative recall again was defined as length of discourse, errors, and order of narrative recall, and was measured using the supplemental scoring system.

3) What is the relationship between the present scoring system on the WRAML and the supplemental scoring system, which measures differences in quality of narrative discourse, i.e., sequential order, number of unrelated details (errors) and narrative length? "Immediate recall" and "delayed recall" subtest scores on the WRAML were compared to scores obtained on the supplemental scoring system that evaluated both

immediate and delayed recall in three areas: order of recall, number of unrelated details (errors), and narrative length.

4) Is there an identifiable pattern to the story details that are remembered more frequently among moderate and severe TBI children and adolescents?

Attempts were made to determine if certain story details more frequently remembered on both the "immediate recall" and "delayed recall" tasks, and a comparison was made between groups (severity, age).

CHAPTER 3

METHOD

Participants

Subjects were English-speaking children and adolescents between the ages of six and seventeen who were hospitalized because of an acute moderate or severe head injury and did not have a significant history of psychiatric or neurological problems. Patients were given a standard neuropsychological assessment prior to their discharge from the hospital. Included in the battery was a WISC-III and either a full WRAML battery or WRAML-Screener with Story Recognition, and test scores were contained in the patient's hospital records.

After institutional board approval, medical records were reviewed of all rehabilitation/transitional care patients referred to for neuropsychological services over the last six years at Cook Children’s Hospital. Over 300 patients were referred, and out of these, a total of 171 were referred following a traumatic brain injury event. Careful inspection of patient records for these 171 patients revealed only 66 met strict criteria for being included in the sample group. The majority of those not included were either not administered the appropriate tests, were younger than 6 years or were older than 16 years, 11 months.

The 66 remaining subjects were subsequently included in the sample group. These patients ranged in age between the ages of 6 and 16, were in the hospital because of a traumatic brain injury and were administered psychological tests within the hospital setting. They included 44 males and 22 females between the ages of 6 years, 4 months to 16 years, 9 months. Although the mean age of the TBI group (11 years, 11 months) was similar to the control group (11 years, 5 months), the TBI group was slightly older overall with a median age of 12 years, 4 months.

Preliminary data indicated that the 66 subjects closely represented the larger aggregate group in terms of demographics, background information and clinical presentation (see Appendix). Premorbid health and academic history which was obtained from medical records indicated 65% had no reported premorbid learning problems, 13.6% suffered from low grades and 21.2% received some degree of resource room assistance from the school on a daily basis. 64 of the 66 children (97%) had no history of prior head injury and no substance abuse history. 48 children were in good premorbid health, two were born prematurely, one had asthma and one had reported history of seizures. Forty-two of the sixty-six children sustained injuries through a car or boat collision or pedestrian/car collision. Eleven children were injured from slower speed collisions such as skiing, skateboarding or bikes; seven children had fallen from a precipice such as a house, horse, or slow-moving vehicle; five were assaulted, and one was hit by a falling beam. Six of the children had lost an immediate family member in the accident, three children had a premorbid history of depression and/or anxiety.

Injury severity was based on the lowest documented post-resuscitation Glasgow Coma Scale (GCS: Teasdale & Jennett, 1974) score within the first 24 hours after injury, in conjunction with neuroimaging findings, according to the criteria specified by Williams, Levin, and Eisenberg (1990). Using this combined criteria, no injuries were classified mild, 19 were classified moderate and 47 were classified severe. Additionally, the injuries were divided into the following categories: Focal, Multiple focal, Diffuse/Undifferentiated/ Gunshot wound. A separate classification was made which divided injuries into Cortical only, Subcortical only and both Cortical/Subcortical involvement. CT scans were given to 44 of the patients, and the remaining 22 were given an MRI either initially or as a follow-up while in the hospital. Injury location was based on neuroimaging findings and were classified into exclusive categories: left only, right only, frontal only, bilateral without frontal involvement, and bilateral with frontal involvement. Sample group included 13 left hemisphere, 11 right hemisphere, 14 frontal lobe, five bilateral/mid-brain involvement only, and 17 bilateral/mid-brain involvement including frontal involvement. The remaining six neuroimaging scans were CT scans read as “normal” by the radiologist with no specific injury location detected. Four of these six were classified as “severe” based on initial GCS score and two were classified as “moderate”. The majority of the children had a GCS score of less than 8. Injuries included multiple focal lesions (n=32), diffuse/undifferentiated (n=19), or focal (n=15) intracranial lesions. The following table demonstrates these classifications.

Table 1. Frequency of Injury Location: Three separate methods of categorization

	TBI Group (n=66)	
	n	%
Locations – Grouping #1		
Left only		
Right only	11	16.7
Frontal only	14	21.2
Bilateral nonfrontal	5	7.6
Bilateral w/frontal	17	25.8
Normal	6	9.1
Locations – Grouping #2		
Focal	15	22.7
Multifocal	32	48.5
Diffuse/undifferentiated	19	28.8
Locations – Grouping #3		
Cortical only	29	43.9
Subcortical only	6	9.1
Cortical & Subcortical	31	47.0
Severity		
Mild	0	0
Moderate	19	28.8
Severe	47	71.2
Neuroimaging Scans		
MRI	22	33.3
CT	44	66.7
Follow up scan done	49	74.2
No follow up scan	17	25.8
Avg. # Days post scan	20.1	29.0
Cranial Surgery		
No	53	80.3
Yes	13	19.7

Due to unequal cell sizes, the “normal” scans in Grouping #1 were eliminated and the “bilateral” groups were combined. The four resultant categories were left, right, frontal and bilateral. In addition, the “subcortical only” cell in Grouping #3 was combined with the Cortical/Subcortical group due to its small size and lack of homogeneity, leaving only two cells in Grouping #3 instead of three. A comparison of means and standard deviations among these different classification systems can be found in the Appendix (Tables 11,12,13).

Of the 66 children who were included in the study, 50% had been tested and narrative recorded by the director of the Psychology/Neuropsychology department at CCMC. The remainder of the assessments were fairly evenly distributed among other LPAs or psychology externs within the department under her supervision. Elapsed time from initial injury to testing ranged from seven to 234 days, with a mean of 53 days. There was no significant difference between the injury severity groups in terms of age or gender. However, the oldest age group (15-16 year olds) had a longer elapsed time since injury when compared to the other TBI children and there were a greater percentage of severe TBIs within this age group as well. Average elapsed time since injury was 98 days in the older group compared with 33 to 49 days among the rest. In order to minimize cell size differences, age was subdivided into five moderately equal cells sizes: 6-7 (n=10), 8-10 (n=13), 11-12 (n=14), 13-14 (n=13) and 15-16 (n=16). Age was significantly correlated with number of days post injury and severity as shown on the following table. It was not significantly related to premorbid learning problems or performance on the standardized administered tests (see Appendix: Table 14 and Table 15).

Control group data included 16 children ranging in age from 7 years, 5 months to 15 years, 4 months. These children were voluntary participants who were tested by this investigator while inpatients at CCMC. After appropriate institutional board approval (see Appendix), children who were hospitalized for a non-neurological reason and met demographic criteria were randomly given the opportunity to participate in the study. Premorbid health and academic history was obtained, and they received a small thank you gift. A comparison of gender and premorbid history among the TBI and control group is shown on the table below.

Table 2. Frequency Table of Gender and Premorbid history

	TBI Group (n=66)		Control Group (n=16)	
	n	%	n	%
Male	43	65.2	2	12.5
Female	22	33.3	14	87.5
Special Ed/Resource	14	21.2	3	18.8
Poor grades	9	13.6	1	6.3
No academic problems	43	65.2	12	75.0
No premorbid ADHD	55	83.3	15	93.8
Premorbid ADHD	6	9.1	--	--
Suspected ADHD (school or parents)	5	7.6	1	6.3
Health History:				
Good	48	72.7	11	68.8
Premature birth	2	3.0	--	--
Anxiety	1	1.5	--	--
Depression	7	10.6	1	6.3
Asthma	1	1.5	--	--
Grief	6	9.1	--	--
Seizure History	1	1.5	--	--

To obtain a measure of attentional abilities and general cognitive functioning, vocabulary, block design, arithmetic and digit span subtests from the WISC were given.

The WRAML Story Memory subtest was also administered, and verbal recall of the stories were hand-recorded in a similar fashion to recordings done with the TBI study group. A comparison of the TBI and control group in regards to mean age and performance across tests is demonstrated on the following table.

Table 3. Means and Standard Deviations of TBI and Control Group

	TBI Group (n=66)			Control Group (n=16)		
	x	SD	n	x	SD	n
Tested age (in mos.)	143.9	38.4	66	137	31.1	16
Age at injury	143.7	38.1	66	--	--	--
# Days post injury	53.9	46.8	66	--	--	--
GCS	6.7	3.5	66	--	--	--
WISC:						
FSIQ	78.02	17.6	66	--	--	--
VIQ	82.2	17.6	66	--	--	--
PIQ	77.3	18.9	64	--	--	--
Information	6.8	3.4	57	--	--	--
Picture Arr.	5.0	2.8	55	--	--	--
Arithmetic	7.7	3.9	57	8.5	3.4	16
Block Design	7.1	3.9	56	9.0	3.7	16
Vocabulary	6.2	3.4	57	7.3	4.0	16
Digit Span	8.5	5.2	53	8.4	2.9	16
WRAML						
Verbal Memory	81.2	13.1	13	--	--	--
Learning Memory	87.7	25.4	13	--	--	--
Verbal Learning	6.3	3.2	65			
Story Memory	5.9	3.0	66	7.6	3.3	16
Story Recognition	8.6	3.3	47	--	--	--
Story A Immed	6.5	4.1	15	7.6	3.3	3
Story B Immed	8.7	4.6	66	10.8	5.4	16
Story C Immed	7.2	5.4	51	9.8	5.0	13
Total Immed	15.7	8.7	66	20.3	8.9	16
Story A Delay	5.3	4.4	15	7.3	1.2	3
Story B Delay	6.6	5.4	66	10.1	6.2	16
Story C Delay	5.1	5.3	51	8.8	5.3	13
Total Delay	11.8	9.4	66	18.3	10.3	16
Immed minus Delay	4.1	4.6	66	2.1	4.0	16

Within both the TBI and control group, age was not found to be significantly related to premorbid learning problems or performance on the administered standardized tests.

Instruments

Wide Range Assessment of Memory and Learning (WRAML)

The WRAML is a carefully standardized psychometric instrument that allows the user to evaluate a child's ability to actively learn and memorize a variety of information. (Sheslow & Adams, 1990). It has been widely accepted as an effective measurement of pervasive memory deficits of the pediatric TBI population. Norms were standardized for children ranging in age from 5 years, 0 months to 17 years, 11 months. The normed group was a stratified sample of 2363 individuals, controlled for age, sex, race, regional residence and metropolitan vs. non-metropolitan residence. It is designed to assess modality specific competencies (i.e., visual vs. verbal deficits). It also measures differences in recall along an episodic-semantic continuum, meaning that some subtests require remembering discrete, non-meaningful bits of information, and others require remembering semantically loaded, meaningful information. It allows for the assessment of immediate vs. delayed recall vs. recognition memory. Test-retest reliability for the General Memory Index (overall index) is .84. Coefficient alpha for the Verbal Memory Index is .93. Coefficient alpha for the Learning Index is.91.

An example of the Story Memory subtest is included in the Appendix. On this subtest, two short stories are read and the child is asked to recall as many parts of each story as can be remembered. The stories are developed with differing developmental levels of interest and linguistic complexity. Both a delayed recall and a delayed recognition task are provided for this subtest. On the delayed recognition task, guidelines are provided to determine whether the level of recall performance was "Bright Average," "Average," "Low Average," "Borderline" or "Atypical" when compared to peers, which is based on the number of facts answered correctly in a T or F format (Sheslow & Adams, 1990). In the Story Memory subtest, the child is told, "I am going to read you a story. Listen very carefully because when I am done, I will ask you to tell me as much of the story as you can remember." The task can be clarified if the child has any questions. The first of two stories is then read to the child with "speed and inflection appropriate to reading a story in an interesting manner". After the story is read, the examiner asks the child, "Now, tell me the story. Try to tell me all the parts." When the child has finished recalling the first story, the examiner repeats the same instructions before reading a second story with slightly more linguistic complexity. The child is then asked to recall as much of the second story as they can. Approximately thirty minutes later the child is asked once again to recall as much of the stories as possible in order to quickly screen for decay of learning (i.e., forgetting) following an intervening task. The scoring criteria remains the same. A total recall score is obtained by combining the total number of points given from the two story recall trials. There are three stories on the subtest. Children eight years old and younger are given stories A and B, and children nine and above are given stories B and C. The child is given a point for recalling either verbatim words or thematic statements. Items listed on the Examiner form which are in upper case letters must be exactly recalled to receive credit, and items listed in lower case letters may be phrased "differently, providing that the meaning is preserved." Detailed scoring guidelines are also provided, regardless of the order in which they were recalled.

According to principal components analysis with varimax rotation, the Story Memory subtest loads principally on the Learning Index Component (.585). Confidence interval for the General Memory Index is +/- 6 points from the obtained score. On the WRAML, there are significantly positive correlations between raw score performance and age on each of the nine subtests (Sheslow & Adams, 1990).

Supplemental Scoring System

A supplemental quality analysis/scoring system for the WRAML was created and utilized for the purposes of this study (see Appendix). Following Kintsch & van Dijk's model of hierarchical structure, quality of recall was determined based on the following measures: 1) the presence or absence of key terms or phrases in the present scoring system, 2) incorrect sequencing of the story, 3) additions or extraneous information given in recall that was not part of the original story. The child's recall of the stories had been previously recorded on a separate sheet of paper by the initial examiner. Quality was measured by scoring the discourse according to the following criteria: 1) Was the story retold in sequential order? 2) How many unrelated additions did the child make to the story? and 3) What was the overall discourse length?

Order. Two separate scores were created. The first reflected the order of specific details. The second reflected the order of main events. In this manner, a measure of both the microstructure and macrostructure during recall was obtained by counting the number of details or events recalled out of order. To obtain a more accurate measure of the degree of error, the distance or degree of disorganization was quantified by computing the “error distance”; the difference between where the event or detail was actually recalled and the correct order of the detail or event as it appears in the story.

Errors. Unrelated additions such as details, people or actions were counted and a score was given based on the total number of words used in the unrelated (extraneous) details given.

Length. The total number of words in the recall was used as a measurement of discourse length. All recorded words were counted except for “a”.

Wechsler Intelligence Scale for Children, Third Edition (WISC-III)

The WISC-III is a widely accepted instrument designed to measure both verbal and nonverbal intelligence. It is normed for ages 6 to 16 years, 11 months. Performance on the Digit Span and Arithmetic subtests were used as a measure of attenuation among these children, and provided a verbal attention measure separate from verbal memory. Digit span has a test-retest reliability of .73 and Arithmetic has a test-retest reliability of .74. They are moderately correlated (r = .43). In addition, the Vocabulary and Information subtests were used as measures of premorbid language abilities. These subtests are highly correlated (r = .70). Test-retest reliability on both tests is above .80.

Glasgow Coma Scale

Level of severity was measured using the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) in conjunction with neuroimaging findings. It is widely used in studies and has demonstrated itself to be an adequate research tool as a measure of severity (Goldstein, Levin & Eisenberg, 1992). When the GCS score was plotted against mortality in a study performed by Rimel and his colleagues (1982), there was almost linear relationship between mortality and GCS scores up to 11. GCS scores above 11 were less predictive. Another study which compared clinical, radiologic and serum marker as prognostic factors after severe head injury, found initial GCS scores of less than 9 were 66% accurate in predicting long-term outcome (Woertgen, Rothoerl, Metz & Brawanski, 1999). A GCS of less than 9 means no eye opening, an inability to obey commands, and an inability to utter comprehensible words at the time of hospital admission. Using a GCS score threshold of less than 9 within the first 48 hours of injury, a study of San Diego County for 1981 found 14 cases of severe TBI per 100,000, with a case-fatality rate of 58% (Marion, 1999). These studies, among others (Levi, Drotar, Yeates & Taylor, 1999 and Martin, Donders & Thompson, 2000), and including the Brain Trauma Research Center at the University of Pittsburgh Medical Center, classified injuries as moderate if the lowest GCS fell between 9 and 12 as recorded by the emergency medical staff. GCS scores below 9 were classified as severe, and scores above 12 were classified as mild. Levi, et al. (1999), Levin, Eisenberg, et al. (1988), Marion (1999) and Martin, et al. (2000) additionally classified injuries as moderate if the GCS was greater than 12, but was concomitant with a skull fracture, intracranial mass lesion or contusion, diffuse cerebral swelling, posttraumatic neurological abnormality or a documented loss of consciousness of more than 15 minutes. A consensus definition of mild brain injury, published by the Mild Traumatic Brain Injury Committee of the Brain Injury Interdisciplinary Special Interest Group (BISIG) of the American Congress of Rehabilitation Medicine, is defined as loss of consciousness not exceeding more than 30 minutes, an initial GCS score of 13 to 15 after 30 minutes, and PTA not exceeding 24 hours.

Emergency personnel may have difficulty evaluating the verbal responses of children using the GCS. For this reason, the GCS scales are often supplemented with younger children's verbal responses. This results in a Pediatric Coma Scale Score (PCS) which has identical "eye opening" and "motor response" scales as the GCS but the "verbal response" scale includes younger children's verbal responses (see Appendix).

Neuroimaging Studies

Neuroimaging studies are located in the patients' hospital records. Information obtained from a follow-up magnetic resonance image (MRI) or computerized tomography (CT) of the brain was used to determine localization of injury and to identify focal versus diffuse damage. Focal damage included contusions, hematomas or lesions, and the identified area of focal damage was determined by referring to the radiologist's report. In the same manner, diffuse damage identified by the radiologist was be labeled the same way for purposes of the study. Patients who were given a GCS greater than 12, but demonstrated post-traumatic neurological changes such as an intracranial mass lesion, contusion, diffuse cerebral swelling, or skull fracture on the follow-up MRI or CT scan were classified as having a moderate injury.

Procedure

Overall Story Length. Every word that the child used during recall that had been recorded by the examiner was tallied, with the exception of the word “a”. The written recordings were made by nine examiners. The total number of words became the story length score, and the amount of inter-rater agreement was evaluated by comparing the mean story lengths recorded by all nine examiners. Fifty-five percent of the patients were examined by one individual, and the remainder forty-five percent were examined by eight others, some of whom had recorded a total of only two or three narratives.

Story Macrostructure. To measure the child’s understanding of the gist of the story, the number of propositions and the order in which they were remembered by the child was tallied. For purposes of this study, a proposition was defined as a single event that occurred in the story. The first story contained six main events, the second had six events and the third story had six main events (see Appendix).

Story Microstructure. How well the child remembered the details of the story was looked at in terms of order (how well did the child recall the story, including details, in order) and errors (how well did the child stay true to the story without adding additional details that did not belong). The number of details had been previously tallied and comprised the WRAML standard score.

CHAPTER 4

RESULTS

Preliminary analysis began by determining if there was a significant relationship between independent variables such as age, location, severity which might significantly influence the results. Using the classifications of left, right, frontal and bilateral, as well as the separate classification of cortical versus cortical/subcortical, crosstabulations revealed the study group to be relatively homogeneous in terms of age, gender, severity and level of functioning.

Reliability of the supplemental scoring system was then measured by having two examiners simultaneously record the responses of five separate subjects. Subsequent scores from the two examiners were compared for all five protocols using the supplemental scoring system. As shown on Table 4, there were strong correlations across all three measures (length of discourse, errors, order of recall). The internal consistency of all three variables was adequate (Cronbach's alpha .40).

Table 4. Supplemental Scoring System: Degree of Inter-rater reliability

	Examiner A (x)	Examiner B (x)	r
Overall Story Length	80.6	87.2	.997**
Commission Errors	13.6	13.6	.992**
Story Events	9.0	8.8	.987**
Order of Events	.4	.4	1.0**
Degree of Error (Events)	1.8	1.8	1.0**
Order of Details*	2.4	2.4	1.0**
Degree of Error (Details)	14.8	16.4	.997**

* WRAML standard score already tallies the *number* of details remembered, and was not included in the supplemental scoring system.

The assumption was made that if there were individual differences in the absolute length of the stories among the children in either the TBI or control group, then this would have an effect on every other dependent variable in the data set. For this reason, group effects in overall story length were examined first. Table 5 shows the differences in mean story length across examiners.

Table 5. Mean story length x examiners

	Length – Immed.		Length- Delay		Total Length	
	x	SD	x	SD	x	SD
Examiners:						
#1	48.9	21.9	35.8	25.5	84.7	42.4
#2	77.7	35.3	70.0	44.4	147.7	74.4
#3	80.4	36.5	57.8	51.0	138.1	85.0
#4	82.0	32.5	92.7	45.4	174.7	77.7
#5	82.8	31.8	74.4	26.2	157.2	56.2
#6	50.5	27.6	62.5	41.7	113.0	69.3
#7	55.0	35.4	60.5	48.8	115.5	84.1
#8	63.7	47.4	59.3	51.5	123.0	98.9
#9	55.0	41.7	41.7	41.5	96.7	79.4

Among the dependent variables used, there was a significant difference in the story lengths across examiners, but the number of errors and story order did not vary significantly across examiners. One possible reason for this was that the recording of the narratives was not standardized and some examiners may have omitted minor words such as “the”, “and” or “but” while other examiners recorded the verbatim response. In addition, the childrens’ ages were not consistent across examiners, and this may have affected differences in mean story lengths, as well.

The correlation between story length and other dependent variables such as commission errors, event order and detail order was significant as shown on the following table.

Table 6. Overall Story Length x Story Order and Extraneous Details (TBI Group)

Length:	Immed	Delay	Total
Length – I	1.0**	.80**	.93**
Length – D	.80**	1.0**	.96**
Total Length	.94**	.96**	1.0**
Extraneous Details – I	.42**	.16	.29*
Extraneous Details – D	.51**	.63**	.61*
Total Extra. Details	.55**	.46**	.53**
#Events – I	.77**	.16	.78**
#Events – D	.70**	.63**	.84**
Total # Events	.76**	.83**	.84**
Order of Events – I	.28*	.33**	.78**
Order of Events – D	.30*	.34**	.84**
Total Order of Events	.31*	.37**	.36**
Distance Error (Events) – I	.28*	.25*	.28*
Distance Error (Events) – D	.25*	.26*	.27*
Total Error (Events)	.31*	.30*	.32**
Order of Details – I	.44**	.43**	.46**
Order of Details – D	.55**	.56**	.58**
Total Order of Details	.54**	.54**	.57**
Distance Error (Details) – I	.55**	.46**	.53**
Distance Error (Details) – D	.41**	.44**	.45**
Total Error (Details)	.54**	.50**	.55**

* = $p < .05$ ** = $p < .01$

One-way analysis of variance did not reveal a significant effect of age ($F(1,59) = 1.03$, $p < .56$), or severity ($F(1,59) = 2.16$, $p < .20$) on story length. Subsequent ANOVAs did not demonstrate a significant effect when injury location was classified as either left, right, frontal or bilateral ($F(1,59) = 1.23$, $p < .43$), or when injury location was classified as either cortical or cortical/subcortical ($F(1,59) = .83$, $p < .68$).

The overall story length of the TBI group over both trials was then compared with normal controls. Levine's test for equal variances found both groups to be acceptable ($F(1,74) = .15$, $p. < .70$). Results demonstrated that the overall story length did not differ significantly between groups ($F(1,74) = .62$, $p. < .88$). However, differences were seen in story length during delayed recall. There was a significant loss of recall among the TBI during delay recall in terms of story length ($F(1,59)= 3.58$, $p. <.01$), whereas the control group provided a relatively consistent story length across time ($F(1,15)=194.29$, $p. <.06$). This resulted in a significant difference in story length during delayed recall between the TBI patients and controls ($F(1,74) = 3.89$, $p. < .052$).

Research Question #1: Is there a significant relationship between the injury location and length of discourse, errors, and order of narrative recall?

The macrostructure of the narrative recall was defined by tallying the number of events and the order of their recall. An analysis of variance did not demonstrate significant main effects of location when classified as left, right, frontal or bilateral on total number of recalled events ($F(3,56) = 2.04$, $p. <.12$), or the organization of the events recalled ($F(3,56) = .86$, $p. <.47$). There was a tendency for frontal lobe injuries to remember fewer events during delayed recall ($F(3,56) = 2.78$, $p. <.05$), however, the effect size was very small (.06). A separate analysis of variance also did not demonstrate a significant effect of location when defined as either cortical or cortical/subcortical on total number of events recalled ($F(1,58) =.12$, $p. <.73$) or the organization of the events recalled ($F(1,58) = .49$, $p. < .49$). No significant differences were found for either group during immediate or delayed recall in terms of recalled events.

The microstructure of the narrative recall was defined by the number and organization of details remembered. Using univariate analysis of variance, no main effects of location (left, right, frontal, bilateral) were seen on the number of details remembered ($\underline{F}(3,56)=1.67$, $\underline{p}.<.19$) or the organization of the details ($\underline{F}(3,56)=.73$, $\underline{p}.<.54$). A second analysis which classified location as cortical or a combination of cortical/subcortical also did not demonstrate a main effect on number of details remembered ($\underline{F}(1,58) = .20$, $\underline{p}.<.66$) or detail order ($\underline{F}(1,58) = 2.0$, $\underline{p}.<.17$). Neither group demonstrated significant differences between immediate and delayed recall of details or detail order.

Lastly, the children's narratives were examined for the addition of extraneous details. Analysis of variance indicated a significant main effect of location (left, right, frontal, bilateral) on total number of commission errors. There were significantly more commission errors among right hemispheric injuries when compared with frontal lobe injuries in general ($\underline{F}(3,56) = 2.74$, $\underline{p}.<.05$), and particularly during immediate recall ($\underline{F}(3,56) = 3.43$, $\underline{p}.<.02$). When injuries were re-classified as cortical versus subcortical involvement, significantly more commission errors were made during immediate recall by the subcortical group ($\underline{F}(1,58) = 7.40$, $\underline{p}.<.01$), but overall differences were much less pronounced ($\underline{F}(1,58) = 3.36$, $\underline{p}.<.07$).

Research Question #2: Is there a significant relationship between age at injury and length of discourse, errors, and order of narrative recall?

A comparison of the means and standard deviations by age and the overall means and standard deviations for both the TBI and control group is shown on Table 7.

Table 7. Age x Supplemental Scoring System, WRAML Standard Scores

TBI ages:	6-7		8-10		11-12		13-14		15-16		TBI		Controls	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
Length														
Immediate	36.6	16.9	58.0	27.0	60.6	32.0	83.3	29.6	61.1	31.1	61.0	30.9	75.3	28.6
Delayed	33.7	29.1	50.3	34.0	41.8	31.8	76.8	38.3	47.3	40.9	50.5	37.3	70.3	32.5
Total	70.3	42.6	108.3	56.1	102.4	60.9	160.2	65.6	108.3	67.9	111.5	64.7	145.6	59.5
Commission Errors														
Immediate	5.1	5.2	16.9	17.1	12.6	7.8	10.5	6.5	10.5	7.6	11.4	10.2	8.9	8.9
Delayed	9.1	12.5	17.8	14.4	8.6	7.8	13.1	9.1	7.6	5.5	11.1	10.4	9.1	11.6
Total	14.2	6.3	34.7	27.2	21.1	14.4	23.5	12.9	18.1	9.5	22.5	17.7	18.0	20.0
# of Events														
Immediate	4.3	2.8	6.1	3.5	5.5	3.0	7.5	3.0	5.8	3.4	5.9	3.2	6.8	3.0
Delayed	3.5	3.2	5.1	3.5	4.1	2.8	6.7	3.5	4.9	4.3	4.9	3.6	6.6	3.1
Total	7.9	5.3	11.2	6.9	9.6	5.4	14.2	6.3	10.7	7.4	10.8	6.5	13.4	6.0
Order of Events														
Immediate	.40	.70	.46	.66	.50	1.1	.38	.87	.38	.62	.42	.79	3.1	1.6
Delayed	.00	.00	.38	.77	.50	1.1	.53	1.1	.13	.50	.32	.83	3.0	1.5
Total	.40	.70	.85	1.3	1.0	2.1	.92	1.9	.50	1.0	.74	1.50	6.1	2.6
Distance Error														
Immediate	1.0	2.5	1.3	1.9	1.6	3.2	.46	1.7	.75	1.8	1.0	2.2	.88	2.2
Delayed	.00	.00	.77	1.5	1.6	3.5	.77	1.7	.31	1.3	.73	2.0	1.0	2.4
Total	1.0	2.5	2.1	3.1	3.3	6.0	1.2	2.2	1.1	2.9	1.8	3.7	1.9	3.8
Order of Details														
Immediate	1.3	1.1	1.6	1.4	2.6	3.7	2.8	1.8	2.0	1.8	2.1	2.2	3.1	1.6
Delayed	.60	.70	1.6	2.7	1.6	2.3	2.5	2.3	.81	1.2	1.4	2.1	3.0	1.5
Total	1.9	1.4	3.2	3.5	4.2	5.9	5.2	3.7	2.8	2.8	3.5	3.9	6.1	2.6
Distance Error														
Immediate	9.2	10.8	6.5	10.8	17.0	21.6	12.0	12.5	10.5	14.8	11.2	14.9	15.3	22.0
Delayed	2.5	3.4	5.1	9.9	9.9	19.7	11.4	15.7	3.1	5.4	6.5	12.8	13.3	13.3
Total	11.7	10.9	11.6	20.0	26.9	39.2	23.4	22.5	13.6	19.5	17.7	24.9	28.6	28.4
WRAML Scores:														
Immediate	10.3	4.5	13.4	7.9	16.6	7.8	22.1	9.0	15.1	9.3	15.7	8.7	20.3	8.9
Delayed	8.4	6.3	11.0	8.1	10.3	8.5	19.1	10.8	10.1	9.6	11.8	9.4	18.3	10.3
SM Score	6.5	1.5	5.5	3.0	5.6	2.9	7.5	3.5	4.9	3.1	5.9	3.0	7.6	3.3
Recognition	0.0	0.0	6.8	3.5	8.9	2.4	10.4	2.9	7.9	3.6	8.6	3.3	--	--

Univariate analysis of variance did not demonstrate a main effect of age on the macrostructure, i.e., the total number of events recalled ($\underline{F}(4,55) = 1.33$, $\underline{p}.<.27$), or the order of the events recalled ($\underline{F}(4,55) = .39$, $\underline{p}.< .81$). No significant age effects were seen in the number of recalled events during immediate recall ($\underline{F}(4,55) = 1.40$, $\underline{p}.<.25$), or delayed recall ($\underline{F}(4,55) = 1.13$, $\underline{p}.<.35$), or in the order of events during immediate and delayed recall.

Examination of the microstructure also did not reveal a significant main effect of age on overall detail order ($\underline{F}(4,55) = 1.50$, $\underline{p}.<.22$) or the organization of details during immediate ($\underline{F}(4,55) = 1.05$, $\underline{p}.<.39$) or delayed recall ($\underline{F}(4,55) = 1.71$, $\underline{p}.<.16$). The degree of disorganization was also not significantly affected by age.

The possibility of age effects on the number of commission errors was then evaluated using univariate analysis of variance. Significant age effects were seen on the total number of commission errors ($\underline{F}(4,55) = 3.08$, $\underline{p}.<.02$), and errors made during delayed recall ($\underline{F}(4,55) = 2.56$, $\underline{p}.<.05$). Errors made during immediate recall approached significance ($\underline{F}(4,55) = 2.47$, $\underline{p}.<.06$). Tukey's post hoc tests revealed significant differences between the 8-10 age group, who made significantly more commission errors overall when compared to both the 6-7 and 13-14 age groups. A significant difference was seen between the 8-10 age group, and the 13-14 age group during delayed recall, when the younger group also made significantly more errors than the older group.

Lastly, the overall performance of the TBI group was compared to the control group in terms of significant differences that might exist. Analysis of variance did not reveal significant differences in the overall number of commission errors between groups

($F(1,74) = .80$, p.<.37), errors during immediate ($F(1,74) = .65$, p.<.42) or delayed recall ($F(1,74) = .61$, p.<.44). Similar number of events were remembered during immediate recall ($F(1,74) = 1.38$, p.<.24) and during delayed recall between both groups ($F(1,74) = 3.23$, p.<.08). The order of events remembered during immediate recall ($F(1,74) = .85$, p.<.36) or delayed recall ($F(1,74) = .03$, p.<.87) did not differ significantly. Significant differences were found between groups in how organized the details were recalled overall ($F(1,74) = 5.59$, p.<.02) and during delayed recall ($F(1,74) = 7.37$, p.<.01), but not during immediate recall ($F(1,74) = 2.67$, p.<.11).

Research Question #3: Does the present scoring system on the WRAML adequately identify individual differences in length of discourse, errors, and order of narrative recall?

Relationships between the individual's immediate and delayed recall score on the WRAML and the supplemental scores at both immediate and delayed recall were determined using correlation coefficients. As seen in the following table, statistically significant correlations were found between standard Immediate and Delay scores on the WRAML and length of discourse and error distance on the supplemental scoring system. No significant correlation was found, however, between immediate and delay scores, and the number of errors given in the narrative.

Table 8. Relationship of SM Std Score and Quality of Recall

	Story Mem	Age	L/R/F/B	Cort/Sub
Story Memory Standard Score		-.11	-.28*	-.06
Overall Length	.74**	.22	-.21	.11
Commission errors	.15	-.09	-.15	.23
Event Order – Immediate	.87**	-.03	-.00	.09
Event Order - Delayed	.82**	.05	-.08	.08
Order of Details – Immediate	.39**	.11	-.04	.16
Order of Details – Delayed	.48**	.08	-.08	.17
Order of Details – Total	.47**	.11	-.06	.18

**p<.01

Using a partial correlation coefficient and controlling for the Story Memory Standard Score, the relationships between age, and the two separate location classifications to overall story length are substantially increased. There is also a trend toward a stronger relationship between age and the organization of details in the story. The remainder of the relationships remain unaffected.

Table 9. Partial Correlation Coefficients controlling for SM Std Score

	Age	L/R/F/B	Cort/Sub
Overall Length	.44**	-.01	.22
Commission errors	-.09	-.12	.23
Event Order – Immediate	-.03	-.00	.09
Event Order - Delayed	.05	-.08	.08
Order of Details – Immediate	.17	-.04	.16
Order of Details – Delayed	.15	-.08	.17
Order of Details – Total	.18	-.06	.18

**p.<.01

Research Question #4: Is there an identifiable pattern to the story details that are remembered more frequently among moderate and severe TBI children and adolescents?

This question was addressed by determining the nature of each item on the Story Memory subtest, and placing it into one of four categories based on the nature of the item. These categories were Animate, Inanimate, Time and Event. The items were details identified and listed in the story memory subtest manual and were the same items used to determine the standard verbal memory score. The number of items in each category were then counted to obtain a total score for that category. Patterns in both the immediate and delayed recall of the two separate TBI groups (i.e. moderate, severe) were compared in order to determine if there are certain conceptual categories that are more salient than others among these two groups. Inasmuch as younger children (ages 8 and younger) were administered different items than the older children consistent with the standard administration rules of the WRAML, the age groups were evaluated separately. Results indicated that the younger children with severe head injuries were less likely to remember inanimate details than the moderately injured younger children ($F(1,14) = 4.71$, $p.<.05$). No other significant differences were found in the younger group or in the older group between animate, inanimate, time and event items.

Finally, correlations were completed in order to assess the degree to which premorbid factors such as level of IQ, or prior health history might have affected performance. Arithmetic, Vocabulary, Block Design and Digit Span had been administered to 49 of the 66 TBI children, and all of the control group (16) as part of the assessment battery. There was a high correlation between the performance on Vocabulary and Arithmetic and the WRAML Story Memory Standard subtest score in both TBI and control groups (Tables 14 & 15 in Appendix). In addition, there was a strong relationship between performance on the WISC verbal subtests and the number of events recalled by both groups. Premorbid heath history, history of attentional problems, prior academic performance, and/or use of drugs was not significantly related to Story Memory performance in either group.

In summary, these results demonstrate a significant difference in story length among TBI and controls. Narratives given by the TBI group were also less organized overall and during delayed recall. Frontal lobe injuries remembered fewer events during delayed recall. Right hemispheric injuries and/or injuries with subcortical involvement were more likely to make commission errors during recall, and children between the ages of 8-10 made the most commission errors compared to other age groups. The following table summarizes these results.

Table 10. Predictors of Qualitative Recall

	L/R/F/B	Cort/Subcort	Age	TBI /Controls
Overall Story Length	No	No	No	Yes (D)
# of Events/Details	Yes (D)	No	No	No
Recited in Correct Order	No	No	No	Yes (T & D)
# of Extraneous Details	Yes (T & I)	Yes(I)	Yes (T & D)	No

I = Immediate, D = Delayed, T = Total

CHAPTER 5

DISCUSSION

This study explored the potential usefulness of providing a supplemental scoring scale to a standard story recall task which does not take into account differences in story length, the presence of commission errors, or disorganization of recall. These factors, not accounted for by the standard scoring method, may be important predictors of future learning difficulties, such as when the child returns to school and is typically expected to learn a significant amount of new, verbally presented material. Due to the complexity of cognitive processes involved in the remembrance and recall of verbal material, it was proposed that supplemental measures might capture possible subtle differences in quality of recall in relationship to injury severity, location and age, that might otherwise be overlooked by the standard scoring system.

Preliminary findings of this study demonstrated that there were significant differences in how well the Story Memory subtest was recalled, between the control group and TBI patients, primarily in the order of details recalled and in the amount of the story retained after a 30 minute delay. Not only were the re-telling of the stories by the TBI patients more likely to be brief and told out of order after a 30 minute delay. These are not surprising results when taking into account our understanding and knowledge of TBI and its impact on memory processes.

Location in terms of lateralization did not predict the quality of recall with the exception of adding extraneous words into the story, which was an unexpected finding. Specifically, it was expected that frontal lobe injuries would have a more profound effect on the child's ability to organize and recall the story. While frontal lobe injuries remembered fewer events after the 30 minute delay, location was not a significant predictor of narrative organization. However, children who had both cortical and subcortical injuries were more likely to "make-up" details or events within the story.

No significant age differences were found in this study in terms of degree of organization or how much of the "gist" of the story was recalled. The only age difference found was that the 8-10 year olds added more to their stories than their younger or older counterparts. This finding tends to support prior studies that suggest TBI is tolerated equally badly in children of all ages (Dennis, et al.,1995, Ewing-Cobbs, et al., 1997).

Findings also suggest the WRAML Story Memory subtest score is relatively robust in providing information regarding the quality of recall surrounding related details or events initially provided by the story, and significantly correlated with degree of error. However, it is a less accurate in detecting the addition of erroneous information, which might be of clinical value in obtaining a true measure of the child's conceptual understanding of the story. For example, one child's narrative included "… he found three worms under a rock," an incorrect detail which should have been remembered as "…stood on a rock….he used three worms and caught…." In this case, both children received the same score for remembering the story in spite of the very different meanings. Ideally, the scoring should discriminate between the remembrance of the "gist" of the story and verbatim recall. It should identify distortions to the story, the addition of incidental details and the relevancy of intrusions in terms of how closely they resemble the original meaning of the text. It is not uncommon for standardized measures to miss these errors that are often seen in TBI children (Kintsch & van Dijk, 1978, Ewing-Cobbs, et al., 1998, Chapman et al., 1992, 1995, Jordan & Murdoch, 1994).

An informal qualitative measure of the child's retelling of the story by recording the child's verbatim recall might identify when the meaning of the passage is missed, as well as provide valuable information by identifying redundancy, repetition, confabulations, tangientiality, the presence of anomia, aphasia or speech patterns suggestive of cognitive difficulties not captured by the traditional scoring method on this subtest. Additional insights into the memory processes of the patient might also be accomplished by reviewing the identification of the most commonly remembered details, as well as the pattern of recall. It is possible (in theory) that the remembrance of details not frequently remembered as well as extraneous information might be more likely to contain projective material, which may provide further insight into the child's present emotional or social functioning.

Limitations

This study should be viewed as a preliminary step toward establishing a standardized and robust supplemental scoring system that provides additional valuable information not easily identify on standardized verbal memory measures. As such, it has many limitations which can be accounted for and corrected in future studies. The limited size of the study as well as multiple unequal cell group sizes made it difficulty to factor in important variables such as other injury types. History of prior head injury potentially is likely to have shown an effect in a larger sample group, based on evidence that there is a cumulative effect seen after two or more mild concussions on verbal learning and other tasks (Collins, 1999). Future studies might consider including the question of prior head injury in a standardized manner as part of obtaining family history.

It is also unknown to what degree factors such as type of neuroimaging scan, standardized reporting, and elapsed time since injury may have affected the placement of patients in injury location categories. It is also unknown to what degree differences in timing and differences among examiners may have affected the Glasgow Coma Scale score rating. Although every effort was made for accuracy, both location and severity variables were based on archival data provided by multiple emergency team or trauma team personnel, radiologists and neurologists many times from multiple hospitals. Consistent follow-up computerized tomography, or magnetic resonance imaging scans accompanied by standardized forms completed by the radiologists would have provided a more detailed and potentially valuable measure of injury location. Additionally, it would have been helpful to ensure consistency in GCS ratings by standardizing the timing and method by which the GCS rating was given.

There may have been possible effects of ingested medications which affected the children's best performance. Depression and anxiety was identified in patients, but was not quantitatively measured, and its effect on performance could not be effectively measured. A lack of consistency between examiners in the number of words they actually recorded during the re-telling may have contributed to a discrepancy among examiners, making it difficult to accurately assess length of recall among the narratives in the TBI group. This could be controlled for in future studies by instructing all examiners to treat words equally and/or in the same manner prior to administering the WRAML.

As the child returns back into his social and school environment, it should remain an important part of his re-entry to educate the family and teacher(s) concerning any communication, memory and/or learning deficits the child may experience as a result of the brain injury. If these issues are addressed prior to his return to school, it may minimize misunderstandings, reduce the his frustration and position the child to be fully supported in adapting to his strengths and weaknesses. Particularly if the child demonstrates difficulty in remembering complex verbal information, this will be useful feedback to provide to the parents, teacher and child along with recommendations to help create an optimal learning environment during school re-entry. Recommendations might include might include asking the child to repeat back verbal instructions after they are given, encouraging the child to ask for clarification when necessary and providing the child with written instructions or a step-wise list that accompanies verbal information. Memory consolidation will be easier if new verbally presented material is introduced in small units with ample time for review and repetition. Multisensory modalities such as kinesthetic and visual channels should be used whenever possible and the child should sit near the front of the classroom where there are fewer auditory distractions and there is a visual advantage. Older children would benefit from learning good note-taking skills, and may find an organizer or sticky-notes useful to stick on books and folders to help them remember verbal assignments that have been given. They should also be encourage to learn and use mnemonic aids such as verbal mediation or rehearsal to facilitate long-term retrieval.

The more knowledgeable the child, his parents and the teacher are about subtle learning difficulties the child might experience, as well as their knowledge of remediation strategies which are easily included in the school setting, the more likely one can ensure a successful learning experience for the child upon return to the classroom following a significant head injury.

APPENDIX

ID# ________________________

Age: ___ **yrs** ___ **mos** **In Months:** ______
DOI: ___/___/___
Age at injury: ______
 # days post injury ______

WISC Standard Scores:
PC ______
Inf ______
Coding ______
Sim ______
PA ______
Arith ______
BD ______
Vocab ______
OA ______
Comp ______
SS ______
DS ______

FSIQ _____ VIQ _____ PIQ _____

WRAML Standard Scores:
Pic Mem ______
Des Mem ______
Verb Lrn ______
Story Mem ______
Finger Win ______
Sound Sym ______
Senten Mem ______
Visual Lrn ______
Nbr/Letter ______

Verb Mem Index ______
Vis Mem Index ______
Lrn Mem Index ______
GMI/MSI ______
Recog Yes No ______

Examiner:

DOE: ___/___/___
DOB: ___/___/___
Gender: M F

<u>Location:</u> __Left __Right
__Frontal __Bilat w/o F
__Bilat w/F

<u>Type:</u> ___Focal
___Multifocal
___Diffuse/Undiff

___Cortical only
___ Subcortical only
___ Both

<u>Severity:</u> Mild Mod Severe

MRI/CT performed on: ____
Days post injury: _________
Follow-up: Yes No

Lowest GCS/PCS:

Surgery: Yes No
Fracture: No Skeletal
Cranial Craniotomy Debride

History:
Learning disability:
Prior Head Injury:
Drug Abuse:
Health Status:
ADHD:

NOTES:

GLASGOW COMA SCALE DEFINITIONS

EYE OPENING

Spontaneous – indicates arousal mechanisms of brainstem intact; does not necessarily imply awareness

To Speech – response to any verbal approach, whether spoken or shouted, not necessarily the command to open eyes

To Pain – response to painful stimulus; tested by stimulus in limbs, because grimacing associated with supraorbital pressure may cause eyes to close

None – when patient does not open eyes to pain; if eyes closed by swelling, indicate on chart

MOTOR RESPONSE

Obeys Commands – best response possible; must take care not to interpret a grasp reflex or postural adjustment as a command

Localize Pain – stimulus of pain at more than one site causes a limb to move to remove stimulus; recommended way of applying painful stimulus is to use nailbed pressure first; if there is a response, then use stimulation on head, neck, and trunk to determine localization

Flexor Response – may vary from rapid withdrawal to slow response of hemiplegia

Abnormal Flexion – decorticate posturing

Extension to Pain – adduction, internal rotation of shoulder, pronation of forearm

No Response – no motor movement to painful stimulus of any type

VERBAL RESPONSE

Orientated – awareness of self and the environment (PCS = coos, babbles/oriented)

Confused – patient responds to questions in a conversational manner but the responses indicate varying degrees of disorientation and confusion (PCS = irritable, cries/confused)

Inappropriate Speech – intelligible articulation but only in exclamatory or random way, usually by shouting or swearing; no sustained conversation (PCS = cries to pain/inappropriate words)

Incomprehensible Sounds – moaning and groaning but without recognizable words (PCS = moans to pain/inappropriate sounds)

None – no sounds being uttered; note if intubated or trached(PCS = none)

MOTOR KEY

5 = Normal
4 = Movement against resistance, but not normal power
3 = Movement against gravity, but not resistance
2 = Movement, but not against gravity
1 = Contraction, but not movement
0 = No contraction

AGGREGATE GROUP (N = 171)			PROPOSED SAMPLE GROUP (n = 66)
Mean Age:	11 years, 6 months		11 years, 0 months
Gender:	68% male, 32% female		66.7 male, 33.3% female
Scan Type:	68.2% CT, 31.8% MRI		66.7% CT, 33.3% MRI
Follow-up scan done?	Yes = 72%		Yes = 74%
	Mean = 18 days		Mean = 20 days
Location of injury:			
Left involvement only		22.9	24.2
Right involvement only		19.3	21.2
Frontal involvement only		19.2	19.7
Bilateral w/o frontal involvement		11.0	10.6
Bilateral with frontal involvement		19.3	18.2
Normal scan		8.3	6.1
Initial Glascow Coma Score:		8.3	7.1
FSIQ:	78.74 (SD = 17.10)		78.0 (SD = 17.5)
Tested with:	WISC 82.4%		WISC 84.8%
	Other 9.9%		Other 12.1%
	Estimated 7.7%		Estimated 3.0%
Premorbid academic history:			
No learning problems		65.8	65.2
Resource Room		21.1	21.2
Low grades		13.2	13.6
Prior ADHD diagnosis		9.6	9.1
Suspected ADHD		7.0	7.6
Premorbid health history:			
Good health		74.6	72.7
Depression		9.6	10.6
Acute Grief		8.8	9.1
Reported drug use		3.6	3.0
Anxiety		2.6	1.6
Premature		1.8	3.0
Past Seizures		1.8	1.5
Asthma		.9	1.5

Event #1: Birthday party

ELIZABETH
EIGHTH
BIRTHDAY
SURPRISE
PARTY

Event #2: Mother made treat

mother
favorite treat
VANILLA
ICE CREAM
CHERRIES
grandfather's

Event #3: Friends were invited

SIX FRIENDS

Event #4: Couldn't have party

CHICKEN POX

Event #5: Party was rescheduled

Week
Later
Surprised her
Party
Skating rink

Event #6: Friends and sister came

Friends
Little
SISTER

Total words _______
Extraneous info _______
Events recalled _______
Org. error/Events: _______ Event Error distance: ________
Organ.error/Total #: _______ Total Error distance: ________

Event #1: They went fishing

SATURDAY	**OSCAR**
MICHAEL	walked
Fishing	pond
CAT	

Event #2: Found the boat unusable
- old
- boat
- full of water
- last night's
- rain

Event #3: Boy utilized rock in lieu of boat
- **ROCK**
- Stand on
- Along shore
- Wouldn't get shoes wet

Event #4: Cat did something else
- Oscar slept
- Shady
- **BUSH**

Event #5: Fishing was productive
- **THREE WORMS**
- Caught one
- Small fish

Event #6: Fish was eaten
- Cat ate later

Total words	______		
Extraneous info	______		
# Events recalled	______		
Org. error/Events:	______	Event Error distance:	________
Organ.error/Total #:	______	Total Error distance:	________

Event #1: She heard about a job

Day before
HIGH SCHOOL
GRADUATION
JUDY
SOCCER
COACH
job opening
HOSPITAL
gift shop

Event #2: An interview was set up

Stopped after school
TWO-PAGE
application
interview scheduled
THURSDAY

Event #3: She got the job

Good luck bracelet
Store manager
MR. STONE
Start right away

Event #4: Hours and salary were set up on schedule

FIVE DOLLARS AN HOUR
SIX HOURS A DAY
Mondays off
Enjoyed work

Event #5: Earned money

Earned money
MORE THAN $500

Event #6: Invited to come back

Invitation to return
Next June
ASSISTANT MANAGER

Total words ______
Extraneous info ______
Events recalled ______
Org. error/Events: ______
Organ.error/Total #: ______

Event Error distance: ________
Total Error distance: ________

Interrater Reliability

Record #1

Organization

	Examiner A	Examiner B
Story 1		
Story 2		

Extra/Erroneous Details

Story 1	Examiner A	Examiner B
Story 2		

Narrative Length

Story 1	Examiner A	Examiner B
Story 2		

Record #2

Organization

	Examiner A	Examiner B
Story 1		
Story 2		

Extra/Erroneous Details

Story 1	Examiner A	Examiner B
Story 2		

Narrative Length

Story 1	Examiner A	Examiner B
Story 2		

Record #3

Organization

	Examiner A	Examiner B
Story 1		
Story 2		

Extra/Erroneous Details

Story 1	Examiner A	Examiner B
Story 2		

Narrative Length

Story 1	Examiner A	Examiner B
Story 2		

Record #4

Organization

	Examiner A	Examiner B
Story 1		
Story 2		

Extra/Erroneous Details

Story 1	Examiner A	Examiner B
Story 2		

Narrative Length

Story 1	Examiner A	Examiner B
Story 2		

Record #5

Organization

	Examiner A	Examiner B
Story 1		
Story 2		

Extra/Erroneous Details

Story 1	Examiner A	Examiner B
Story 2		

Narrative Length

Story 1	Examiner A	Examiner B
Story 2		

COOK CHILDREN'S MEDICAL CENTER

Information Concerning This Study

Do head-injured kids have a harder time remembering stories?

The Psychology Department at the University of North Texas, is conducting a study focused on answering this important question. This study is being conducted by Kathy Thomas, a doctoral student in the Behavioral Medicine Program at UNT. She is studying subtle differences that may exist in memory abilities among children who have had a brain injury of some kind and have spent time in the hospital. Results obtained from the study will hopefully shed light on how we can help these children learn new information more easily when they return to school.

Such memory differences will be better understood if they are compared with the abilities of similar-aged children who have not had a head injury. This is why we would like to give your child the opportunity to participate in the study.

Your child will be given several short cognitive tests that will involve asking him or her to explain the meaning of various words, and remember various items, words and numbers that are given to them. The tests are interesting, challenging and specifically designed for children. The total testing time is expected to take approximately 30-40 minutes and it is not anticipated that your child will experience any discomfort during, or as a result of the tests. Your child will also be given a small gift as a "thank-you" for their participation in the study. All information obtained from the tests will be kept confidential and will be used for research purposes only.

Feel free to call either Ms. Thomas or Dr. Ramos, the Faculty Supervisor at UNT if you should have any questions concerning the study. Thank you for allowing your child to participate.

Kathy Thomas, M.A., Principal Investigator
Ph.D. Candidate, Behavioral Med. Program
UNT Psychology Department
Telephone: (817) 571-5758

Vincent Ramos, Ph.D., Faculty Supervisor
Associate Professor
UNT Psychology Department
(940) 565-4715

This project has been reviewed and approved by the UNT Committee for the Protection of Human Subjects #99-172. Telephone (940) 565-3940, and by the CCMC Institutional Review Board, IRB #232.

COOK CHILDREN'S MEDICAL CENTER

CONSENT FOR CHILD'S PARTICIPATION

I hereby give my consent for my child, ________________________ to participate in a research study designed to better understand the differences in memory ability among children who have had a head injury. I have been told that this research is being conducted by Kathy Thomas, a doctoral student in the Behavioral Medicine Program at UNT, who is studying the abilities of children who have had a brain injury to remember new information. I understand that it is important for these abilities to be compared with similar-aged children who have not had a head injury, and this is why my child has been asked to participate.

I have been told that my child will be given several short cognitive tests that will involve asking the child to explain the meaning of various words, and remember various items, words and numbers that are given to them. These tests are interesting, challenging and specifically designed for children. The total testing time is expected to take approximately 30-40 minutes. There is a possibility that my child may experience some physical or psychological discomfort as a result of the testing, however, it is not expected. If for any reason my child decides to withdraw from participation, the testing will be discontinued and there will be no negative consequences. Potential benefits of the study are to contribute to a deeper understanding of how we can help children who have had a brain injury to learn and remember information more effectively. Should my child decide to complete the testing, he or she will receive a small gift in appreciation for their participation.

I understand that the test scores will be used for research purposes only, and my child will be identified by a number only. All identifying information will be destroyed after the study is completed. No feedback will be available concerning my child's performance and my child's involvement in this study will not in any way affect his or her medical treatment while in the hospital. I will be given a copy of this consent form for my records.

_________________________________ _______________________

Parent **Date**

Should you have any questions or concerns, please call:

Kathy Thomas, M.A., Principal Investigator	Vincent Ramos, Ph.D., Faculty Supervisor
Ph.D. Candidate, Behavioral Med. Program	Associate Professor
UNT Psychology Department	UNT Psychology Department
Telephone: (817) 571-5758	(940) 565-4715

This project has been reviewed and approved by the UNT Committee for the Protection of Human Subjects #99-172. Telephone (940) 565-3940, and by the CCMC Institutional Review Board, IRB #232.

COOK CHILDREN'S MEDICAL CENTER

ASSENT FORM

I ______________________________ agree to take part in this study that is looking at how children who have hurt their head tend to remember things. I have been told that it will take about 30 to 40 minutes to take the tests, and that Ms. Thomas will ask me to do different types of things like answer questions and try to remember what I have been told. Lots of kids take these same tests and they should not make me feel bad in any way. However, I understand that I can change my mind at any time if I decide not to finish the testing and no one will mind. I understand that it will not matter to the doctors or nurses if I take the tests or not. Ms. Thomas will just use the information for her research project and not for anything else. I understand that I will get a small "thank you" gift if I decide to take the tests. I will get to keep a copy of this page in case I have any questions later.

_____________________________________ _________________________

Child's Name Date

This project has been reviewed and approved by the UNT Committee for the Protection of Human Subjects #99-172. Telephone (940) 565-3940, and by the CCMC Institutional Review Board, IRB #232.

COOK CHILDREN'S MEDICAL CENTER

CONSENT FORM

I ______________________________ consent to participate in this study that is looking at how children who have hurt their head tend to remember things. I have been told that it will take about 30 to 40 minutes of my time, and that I will be asked to do different types of cognitive tasks. I understand that I can change my mind at any time about whether or not I want to participate, and that I will not be told about the test results. I understand that whether or not I choose to participate will not in any way affect my medical treatment while in the hospital.

I am not expected to experience any bad feelings as a result of the testing. I understand that the information will be kept confidential and will be used for research purposes only. I understand that everyone's answers will eventually be combined altogether in the end and results will be reported in a group. I understand that all identifying information will be destroyed after the study is completed. I have been told that I can change my mind at any time and for any reason about participating in the study. Ms. Thomas will give me an extra copy of this to keep in case I have any questions later on about the tests and want to call her.

_____________________________________ _________________________

Child's Name Date

This project has been reviewed and approved by the UNT Committee for the Protection of Human Subjects #99-172. Telephone (940) 565-3940, and by the CCMC Institutional Review Board, IRB #232.

REQUEST FOR MODIFICATIONS TO MINIMAL RISK PROTOCOL

Principal Investigator's Name: Kathy Thomas

Faculty Sponsor: Vincent Ramos, Ph.D.

Title of Project: Organization of Narrative Discourse in Children and Adolescents with Acute Traumatic Brain Injury (formerly *Differences in Verbal Strategies Among Children with Hemispheric Effects*)

Permission is being requested to make modifications to the above protocol which was approved by the University of North Texas IRB in September, 1999. These modifications would consist of:

a. Changing the title, formerly Differences in verbal strategies among children with hemispheric effects, to Organization of Narrative Discourse in Children and Adolescents with Acute Traumatic Brain Injury, and

b. Modifying the design of the study to include an inpatient control group (see attached forms providing information for the family, parental consent, and patient consent or assent).

The parents of prospective participants will first be asked by the principal examiner if it is permissible to approach their children. If parental consent is given, the child will then by approached by the principal examiner and asked if they are interested in participating in the study. All children will be approached in an appropriate and non-threatening manner. Should the child or adolescent decide to participate, the parent and the child will be given an information sheet explaining in writing the nature of their child's participation in the study. The principal investigator will carefully review the risks and benefits of the study and the nature of their child's participation with the parent and will ensure that they understand that their child's participation is entirely voluntary. Parents will then be asked to sign the consent form which has been reviewed with them along with the information sheet, and a copy of the signed consent form will be given to the parent. This process will be repeated with the children and either a signed consent form (if the child is 14 or over) or a signed assent form (if the child is under 14) will be left with the child. Every effort will be made to ensure that the child understands that their participation is entirely voluntary.

Each individual assessment will be expected to take no longer than 30 minutes and will be administered by the principal investigator. The assessment will consist of the participant being asked to perform various cognitive tasks that are designed to measure attentional, verbal and memory abilities, and are psychological in nature. These standardized tasks are designed to be given to children. The patient is not expected to experience any physical or psychological discomfort as a result of their participation, and it is expected that most of the participants will find the testing process to be interesting and enjoyable. However, if at any time the patient decides not to participate, the testing will cease immediately. At no time before or during the testing will the patient be made to feel pressure to complete the assessment. The half-hour assessment will be scheduled during a time that is most convenient to the patient and special care will be given to ensure that it will have minimal interference with their regular hospital routine. The patient will be given a small toy in appreciation for their participation in the study.

Possible participants will be patients who are not neurologically impaired and have not reported a significant pre-morbid history of a cognitive or psychiatric disorder. All data obtained will be used for research purposes only and will be reported in aggregate. Data obtained will remain confidential and it will not be possible for the patient to be individually identified from their participation in the study.

Principal Investigator Date

Faculty Sponsor Date

Table 11. Location Means x Supplemental Scoring System, WRAML Standard Scores

	Left		Right		Frontal		Bilateral without front		Bilateral with front		Neg.CT	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
Length – I	75.3	28.6	62.6	28.4	79.5	34.2	49.8	32.2	45.6	36.8	58.5	27.7
Length – D	70.3	32.5	58.7	24.1	70.0	38.6	35.3	31.0	31.6	53.3	48.1	41.2
Total Length	145.6	59.5	121.3	50.2	149.5	67.1	85.1	59.1	77.2	89.7	106.6	65.9
Extra Details – I	8.9	8.9	10.9	7.2	18.5	16.5	5.6	4.5	8.6	3.3	12.2	10.7
Extra Details – D	9.1	11.6	14.5	10.6	14.4	8.3	7.4	7.0	6.0	8.5	12.1	14.1
Total Extra Details	18.0	20.0	25.5	14.9	32.8	21.4	13.1	10.0	14.6	9.6	24.4	22.3
#Events – I	6.8	3.0	6.6	3.4	6.8	3.8	5.0	3.3	4.2	4.0	5.4	2.7
#Events – D	6.6	3.1	6.2	3.1	6.6	4.0	3.6	3.3	2.6	4.0	4.3	3.5
Total # Events	13.4	6.0	12.8	6.3	13.5	7.7	8.6	6.2	6.8	7.8	9.7	5.9
Order/Events – I	.25	.58	.38	.77	.73	1.0	.21	.43	0.0	0.0	.65	1.0
Order/Events – D	.31	.70	.38	.65	.64	1.3	.14	.36	0.0	0.0	.41	1.1
Total Order/Events	.56	1.2	.77	1.2	1.4	2.2	.36	.50	0.0	0.0	1.1	2.0
Distance Error– I	.88	2.2	1.5	3.0	.91	1.6	.71	1.5	0.0	0.0	1.4	2.9
Distance Error – D	1.0	2.4	1.6	2.8	.55	1.3	.29	.73	0.0	0.0	1.0	2.8
Total Error	1.9	3.8	3.2	4.0	1.5	2.8	1.0	1.5	0.0	0.0	2.4	5.6
Order/Details – I	3.1	1.6	2.7	1.7	1.8	1.8	1.6	1.3	1.0	1.0	2.7	3.5
Order/Details – D	3.0	1.5	2.1	2.2	1.1	1.3	1.1	1.1	.80	1.8	1.7	3.1
Total Order/Details	6.1	2.6	4.8	3.5	2.9	2.9	2.6	2.3	1.8	2.5	4.4	6.1
Distance Error – I	15.3	22.0	13.7	10.8	13.3	20.7	8.1	11.5	3.2	3.6	14.6	19.4
Distance Error – D	13.3	13.3	10.9	16.1	4.4	6.1	3.2	4.0	2.8	6.3	9.0	19.5
Total Error/Details	28.6	28.4	24.6	19.5	17.6	26.4	11.3	14.5	6.0	8.5	23.6	37.8
WRAML Scores:												
# Details - I	20.3	8.9	17.5	8.7	19.8	10.5	14.7	9.6	11.6	10.9	12.9	6.1
# Details – D	18.3	10.3	14.3	8.9	15.8	11.0	9.1	9.2	7.4	11.8	10.4	8.1
Story Mem Std Score	7.6	3.3	7.0	2.9	6.8	3.7	5.6	2.8	3.8	4.1	5.3	2.5
Recognition Score	--	--	9.6	3.8	8.7	3.7	9.1	3.8	5.7	.58	7.4	2.7

Table 12. Location Variables x Supplemental Scoring System, WRAML Standard Scores

	Focal		Multifocal		Diffuse/Undiff.		Cortical		Subcortical		Both	
	x	SD	x	SD	x	SD	x	SD	x	SD	x	SD
Length – I	55.9	36.7	62.8	27.8	62.1	32.4	54.6	30.0	40.5	36.0	71.0	28.2
Length – D	49.7	36.4	50.0	33.6	51.9	45.3	48.4	33.3	36.0	47.7	55.2	39.2
Total Length	105.5	69.4	112.8	58.1	113.9	74.3	103.1	59.2	76.5	82.7	125.2	64.2
Extra Details – I	10.1	7.5	10.1	11.3	14.4	1.0	7.6	5.7	7.2	4.2	15.7	12.5
Extra Details – D	10.0	7.1	10.9	9.5	12.4	14.0	10.7	9.2	9.2	10.9	11.9	11.6
Total Extra Details	20.1	13.3	21.0	17.6	26.8	20.8	18.3	13.2	16.3	12.6	27.6	20.9
#Events – I	5.7	3.5	6.5	3.3	4.9	2.9	5.6	2.9	3.2	3.6	6.6	3.2
#Events – D	5.1	3.5	5.3	3.7	4.3	3.5	4.6	3.3	2.8	3.5	5.6	3.7
Total # Events	10.1	6.7	11.8	6.7	9.2	6.1	10.3	5.9	6.0	7.1	12.3	6.6
Order/Events – I	.47	.83	.53	.92	.21	.42	.38	.73	0.0	0.0	.55	.89
Order/Events – D	.40	1.1	.38	.87	.16	.50	.28	.80	0.0	0.0	.42	.92
Total Order/Events	.87	1.8	.91	1.7	.37	.76	.66	1.3	0.0	0.0	.97	1.7
Distance Error– I	.67	1.4	1.5	2.8	.47	1.3	.76	1.9	0.0	0.0	1.5	2.6
Distance Error – D	.67	2.1	1.0	2.4	.32	1.0	.48	1.6	0.0	0.0	1.1	2.5
Total Error	1.3	2.4	2.5	4.7	.79	2.1	1.2	2.3	0.0	0.0	2.6	4.8
Order/Details – I	1.8	1.5	2.3	2.8	1.9	1.3	1.8	1.4	.83	.98	2.6	2.8
Order/Details – D	1.2	1.2	1.5	2.2	1.6	2.4	1.1	1.2	1.3	1.8	1.8	2.7
Total Order/Details	3.0	2.5	3.8	4.7	3.5	3.4	2.8	2.3	2.2	2.2	4.5	5.0
Distance Error – I	10.4	15.6	13.0	16.8	8.7	10.9	9.1	10.6	2.7	3.5	14.8	18.6
Distance Error – D	5.1	7.6	7.4	16.3	6.0	9.0	4.2	6.0	3.7	5.6	9.2	17.3
Total Error/Details	15.5	20.7	20.4	29.9	14.7	18.6	13.3	13.7	6.3	7.4	24.0	32.8
WRAML Scores:												
# Details - I	16.7	9.0	16.3	9.2	13.9	7.6	15.3	8.2	9.7	9.5	17.3	8.7
# Details – D	12.3	10.0	12.3	9.5	10.6	9.2	11.5	9.4	7.0	10.8	13.0	9.1
Story Mem Std Score	6.1	2.7	6.3	3.3	5.1	2.7	6.1	2.8	3.3	3.5	6.3	2.9
Recognition Score	9.5	2.5	6.7	3.9	7.6	2.9	8.8	3.5	6.0	1.4	9.0	3.2

Table 13. Amended Location Variables x Supplemental Scoring System, WRAML Standard Scores

	Focal		Multifocal		Diffuse/Undiff.		Cortical		Cort/Subcort	
	x	SD	x	SD	x	SD	x	SD	x	SD
Length – I	55.9	36.7	62.8	27.8	62.1	32.4	54.6	30.0	66.1	31.2
Length – D	49.7	36.4	50.0	33.6	51.9	45.3	48.4	33.3	52.1	40.6
Total Length	105.5	69.4	112.8	58.1	113.9	74.3	103.1	59.2	118.1	68.8
Extra Details – I	10.1	7.5	10.1	11.3	14.4	1.0	7.6	5.7	14.3	11.9
Extra Details – D	10.0	7.1	10.9	9.5	12.4	14.0	10.7	9.2	11.4	11.4
Total Extra Details	20.1	13.3	21.0	17.6	26.8	20.8	18.3	13.2	25.8	20.1
#Events – I	5.7	3.5	6.5	3.3	4.9	2.9	5.6	2.9	6.1	3.5
#Events – D	5.1	3.5	5.3	3.7	4.3	3.5	4.6	3.3	5.2	3.8
Total # Events	10.1	6.7	11.8	6.7	9.2	6.1	10.3	5.9	11.2	7.0
Order/Events – I	.47	.83	.53	.92	.21	.42	.38	.73	.46	.84
Order/Events – D	.40	1.1	.38	.87	.16	.50	.28	.80	.35	.86
Total Order/Events	.87	1.8	.91	1.7	.37	.76	.66	1.3	.81	1.6
Distance Error– I	.67	1.4	1.5	2.8	.47	1.3	.76	1.9	1.2	2.5
Distance Error – D	.67	2.1	1.0	2.4	.32	1.0	.48	1.6	.92	2.3
Total Error	1.3	2.4	2.5	4.7	.79	2.1	1.2	2.3	2.2	4.5
Order/Details – I	1.8	1.5	2.3	2.8	1.9	1.3	1.8	1.4	2.4	2.6
Order/Details – D	1.2	1.2	1.5	2.2	1.6	2.4	1.1	1.2	1.7	2.5
Total Order/Details	3.0	2.5	3.8	4.7	3.5	3.4	2.8	2.3	4.1	4.7
Distance Error – I	10.4	15.6	13.0	16.8	8.7	10.9	9.1	10.6	12.8	17.6
Distance Error – D	5.1	7.6	7.4	16.3	6.0	9.0	4.2	6.0	8.3	16.1
Total Error/Details	15.5	20.7	20.4	29.9	14.7	18.6	13.3	13.7	21.1	30.7
WRAML Scores:										
# Details - I	16.7	9.0	16.3	9.2	13.9	7.6	15.3	8.2	16.0	9.2
# Details – D	12.3	10.0	12.3	9.5	10.6	9.2	11.5	9.4	12.1	9.5
Story Mem Std Score	6.1	2.7	6.3	3.3	5.1	2.7	6.1	2.8	5.8	3.2
Recognition Score	9.5	2.5	6.7	3.9	7.6	2.9	8.8	3.5	8.4	3.2

Table 14. Relationship between Age, Days post injury, Severity, History of LD, performance on WISC-III, WRAML and Supplemental Scoring System (TBI group)

	Age	#days	Severity	LD	Voc	Info	Arith	DS	PA
Age	1.0	.41**	.26*	-.19	-.10	-.19	.09	-.01	-.32*
# Days post	.41**	1.0	.22	-.03	-.16	-.24	.02	-.32*	-.46**
Severity	.26*	.22	1.0	.01	-.24	-.18	-.01	-.11	-.24
History of LD	-.19	-.03	.01	1.0	.22	.21	.40**	.16	.04
SM Std Score	-.08	-.26*	-.32**	.13	.46**	.57**	.48**	.27	.35**
Total Details – I	.25*	-.14	-.26*	.04	.42**	.47**	.47**	.24	.22
Total Details - D	.14	-.19	-.20	.05	.42**	.46**	.37**	.08	.18
Recognition	.15	-.17	-.18	.09	.38*	.54**	.47**	.32*	.23
Length – I	.28*	.01	-.08	.11	.29*	.34**	.47**	.36**	.03
Length – D	.15	-.17	-.09	.02	.36**	.45**	.37**	.30*	.05
Total Length	.22	-.09	-.09	.06	.35**	.42**	.44**	.34*	.05
Extra Details-I	-.01	.14	.16	.12	-.02	.08	.08	.18	-.12
Extra Details-D	-.15	-.15	-.10	.13	.05	.23	.14	.26	-.12
Total Ex.Details	-.09	-.01	.03	.14	.02	.19	.13	.25	-.14
#Events – I	.13	-.12	-.28*	.04	.44**	.45**	.47**	.19	.26
#Events – D	.12	-.15	-.17	-.04	.45**	.51**	.37**	.17	.21
Total # Events	.13	-.14	-.23	.00	.46**	.50**	.43**	.19	.25
Event Order – I	-.05	-.06	-.13	-.01	.32*	.25	.13	-.07	-.06
Event Order – D	.03	-.14	-.12	-.10	.29*	.26*	.15	-.06	-.01
Total Ev. Order	-.01	-.11	-.13	-.06	.33*	.28*	.15	-.07	-.03
Distance (Eve)-I	-.13	-.11	-.01	.18	.23	.24	.19	.14	-.08
Distance (Eve)-D	.02	-.11	-.01	-.01	.30*	.32*	.21	.06	.01
Total Err(Eve)	-.06	-.13	-.01	.10	.30*	.33*	.23	.12	-.04
Detail Order – I	.12	-.02	.12	.04	.12	.11	.18	.05	.08
Detail Order – D	.07	-.18	-.01	.13	.27*	.33*	.24	.13	.02
Total Det. Order	.11	-.11	.06	.09	.21	.23	.23	.09	-.04
Distance (Det)-I	.08	-.07	-.03	.12	.17	.29*	.23	.16	-.07
Distance (Det)-D	.07	-.11	-.01	.12	.29*	.32*	.25	.10	.01
Total Err (Det)	.09	-.09	-.02	.13	.25	.34**	.27*	.15	-.04

* = p.< .05 ** = p.< .01

Table 15. Relationship between Age, Days post injury, Severity, History of LD, performance on WISC-III subtests, WRAML and Supplemental Scoring System (Control group)

	Age	LD	Voc	Arith	DS
Age	1.0	.18	-.02	-.36	-.41
History of LD	.18	1.0	.33	.33	.39
Story Mem Std Score	-.24	.44	.78**	.69**	.81**
Total Details – Immediate	-.03	.49	.78**	.64**	.70**
Total Details - Delay	.07	.51*	.76**	.60*	.55*
Length – I	.21	.35	.55*	.30	.60*
Length – D	.23	.52*	.61*	.42	.56*
Total Length	.23	.45	.60*	.37	.59*
Extraneous Details – I	.54*	-.25	-.31	-.54*	-.01
Extraneous Details – D	.36	-.22	-.27	-.37	.23
Total Extra. Details	.45	-.24	-.29	-.45	.13
#Events – I	-.13	.54*	.78**	.72**	.62*
#Events – D	-.11	.60*	.68**	.64**	.58*
Total # Events	-.12	.58*	.74**	.68**	.61*
Order of Events – I	-.49	-.32	.08	.24	-.02
Order of Events – D	-.57*	-.21	.22	.24	.17
Total Order of Events	-.56*	-.28	.17	.25	.09
Distance Error (Events) – I	-.30	-.07	.21	.43	.03
Distance Error (Events) – D	-.57*	-.17	.16	.16	.19
Total Error (Events)	-.54*	-.15	.23	.35	.14
Order of Details – I	.18	-.01	.05	.29	-.07
Order of Details – D	-.17	.16	.36	.57*	.20
Total Order of Details	.01	.09	.23	.51*	.07
Distance Error (Details) – I	-.12	.18	.30	.50*	.13
Distance Error (Details) – D	-.20	.11	.66**	.71**	.23
Total Error (Details)	-.19	.19	.54*	.72**	.21

* = $p < .05$ ** = $p < .01$

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